UNIVERSITY OF OREGON

An Environmental Anthropology: The Effects of the Yacyretá Dam on Communities in Misiones, Argentina in Comparison to the Economic and Environmental Well-being of the Pilcomayo River Basin

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Abstract

Do large dam projects create a "sustainable improvement of human welfare" for those directly affected by a dam or not (WCD 2000, 2)? This question is central to a major debate in international development. Scholars have failed to address whether a community suffering from economic hardship would benefit from the construction of a dam, or if there are better means of human welfare development. To determine whether a dam should be built, one must consider the counterfactual: what the community would be like in terms of economic stability, social equality, and environmental sustainability without a dam. This thesis argues that although there may be benefits of leaving a river to run its natural course, the economic gains associated with the implementation of a large hydropower dam bring a greater "sustainable improvement of human welfare" to the community in question (WCD 2000, 2). In particular, despite environmental changes and economic obstacles associated with the Yacyretá Dam, over time, the people that depend on the Paraná River have experienced a significant "sustainable improvement of human welfare" compared to the residents along the Pilcomayo River (WCD 2000, 2). The initial benefits of allowing a river to run freely are the forgone opportunity costs that would be associated with the construction of a dam, such as dam-related downstream and upstream flooding, immediate environmental changes due to the impoundment of the river, avoided construction-induced human and environmental displacement, and the overall financial burden of constructing a large dam and funding its operation. However, economic benefits such as job growth and access to electricity have the potential to outweigh these environmental costs.

Introduction

Large water resource development projects can provide for a "sustainable improvement of human welfare," and to determine whether a dam is economically viable for a community, one must assess its environmental and agricultural sustainability (WCD 2000, 2). The main debate is whether building and operating large dams can induce economic growth and improve the well-being of the communities affected, while minimizing environmental degradation. I find that socioeconomic and environmental conditions of local communities affected by dam construction differ from those without dams. The residents of the Formosa province in Argentina along the undammed Pilcomayo River and the residents of Misiones along the Paraná River near the Yacyretá Dam are impacted by economic changes, such as electricity generation, economic growth, employment, displacement, and the implementation of relocation programs where a dam is present. Natural flooding along with accidental and intentional flooding, industrialization, and the construction of water resource projects, such as the Yacyretá Dam on the Paraná River, are all factors that contribute to the growth of displacement throughout Argentina.

Environmental changes associated with dam construction and operation, such as the impacts of upstream and downstream flooding, displacement as a result of flooding, agricultural harm and biodiversity loss, sedimentation and erosion, and the effects on fisheries are all significant variables when determining the effect of a dam on the surrounding community. The impact of the Yacyretá Dam on communities in the watershed compares to those in communities along the as-yet-undammed Pilcomayo. As indicated by the framework developed by Mike Acreman, Department for International Development, in 2000, there are numerous costs and benefits associated with the construction of a dam, especially in terms of upstream and downstream flooding. This thesis demonstrates that when evaluating upstream impacts, soil

erosion, reservoir sedimentation, and loss of productivity of the flooded area are most relevant to the Pilcomayo/Yacyretá case. Downstream impacts on silt removal, changes in water temperatures, reductions in natural floods, and the loss of access to resources are also important factors when determining whether or not a dam would be ideal for the Pilcomayo River and its ecosystems.

I have compiled a list of factors, seen in Table 1, that indicate whether dams produce a "sustainable improvement of human welfare" (WCD 2000, 2).

Table 1: **Human Welfare Indicator**	**The Pilcomayo River**: *Effects of No Regulation (Cost or Benefit)*	**The Paraná River**: *Impacts of Dams (Cost or Benefit)*
Employment	C	B
Power Generation	C	B
Natural Flooding	C	B- Reduced
Natural Flood-induced Displacement	C	C
Dam-related Downstream Flooding	N/A	C/B
Dam-related Upstream Flooding	N/A	C
Dam Construction-induced Displacement	N/A	C
Upstream Agriculture	C	C
Downstream Agriculture	B	B
Upstream Sedimentation	C	C
Downstream Sedimentation	B	B
Upstream Fisheries	C	C
Downstream Fisheries	B	C
Dam Construction Environmental Changes	N/A	C

I will further explain these factors in the following chapters. The environmental and economic indicators demonstrate how life without a dam, and without water regulation, has its own costs and benefits. Similarly, dams can provide costs and benefits to communities that rely on rivers as a source for survival. In Table 1, the costs refer to a loss to society or a negative impact on human welfare. Benefits, on the other hand, identify where society has gained as a result of a dam, or lack thereof. The construction of the Yacyretá Dam resulted in negative consequences, especially biodiversity loss due to the construction of the reservoir, intentional flooding, and

accidental flooding. In contrast, construction of the reservoir upstream improved water quality downstream, maintained agricultural capabilities, and reduced natural flooding. Overall, the dam, despite the negative environmental consequences, is nonetheless better for human welfare than the undammed option. As demonstrated in Table 1, the benefits seen along the dammed Paraná River outweigh the benefits of allowing a river to run its natural course. To assess these criteria, I will first identify development theories that explain why dams are built and then address how scholars have evaluated the goals for dams and their predominantly economic motives. I will explore how a dam functions throughout its construction and operation stages, and when a dam can be deemed effective. Finally, I will evaluate the impacts of dams on humans as well as the environment and then continue with the selected case study.

Chapter 1: Theory

Goals for Dams

International waterways have caused conflicts over the availability and distribution of resources. When a resource of the commons, a non-excludable public good that lacks defined property rights, is exploited, people and industries that utilize this resource turn to market competition or privatization to fulfill national needs. In response, large dam projects are often implemented in the hope of stimulating economic activity, regulating efficient agriculture, producing energy, or storing water. Dams control irrigation, allow for distribution of clean water resources to communities, and provide the means to develop sustainable agriculture. Dams have the capability to reduce the frequency and damage of minor floods.

Environmental change is a key consequence of water resource management and industrialization. However, when it comes to economically stimulating projects, environmental and social harm is often disregarded because the gains are presumed to be great. Large dam

development projects in the third world reflect ideals of ecological modernization theory (EMT) with the philosophy that the end goal is an image of development similar to that of the industrialized West. When it comes to water resource projects, the core ideas behind the EMT state that:

> Although long-term structural change in technology, population, and the division of labor may create short-term disequilibria…the continued diffusion of modern technologies and social psychology are ultimately triumphant, supplanting the older social, economic, and political matrices of societies experiencing modernization (Kerr, 1960). Thus, the social problems created by structural modernization are temporary by-products of rapid social transformation and are gradually alleviated by adaptive upgrading processes (Murphy, 2000). (Ehrhardt-Martinez et al. 2002, 228)

EMT argues that the immediate, and in some cases long-term, detrimental environmental and social consequences of large technology-based development projects are worth the establishment of a modernized and economically prosperous society. Developing countries that receive funding from international organizations, such as the International Monetary Fund (IMF) or the World Bank, permit large dam projects in hopes of establishing domestic economic growth despite the resulting social and environmental harms that vulnerable local populations face. In addition to factors that influence economic development and agriculture, such as climate change, availability of water resources, and political stability, dams play a major role in altering human welfare. Hydropower dam projects are an example of modernization theory in that they promote the development of new technology. Modernization theory deems a dam to be successful, similarly to the ideals of the World Commission on Dams, when it attains an "advance of human development on a basis that is economically viable" because with available funds, technological projects, such as the development of large hydroelectric dams, have the capability to stimulate economic growth and provide for a sustainable improvement in human welfare (WCD 2000, 2). Ultimately, these development programs encourage a "sense of faith in progress" (Galvan 2011).

The hope is that individuals will become financially invested in the new technology and support its overall goals to provide greater profits and improve economic well-being.

Modernization theory promotes an increase in human welfare; however, such technological motives may not be the most sustainable. Developmental struggles in non-industrialized countries can be rooted in the lack of stable water resources as well as conflicts that have resulted from transitions to democracy. Therefore, it is crucial to consider both economic and environmental consequences that may result from a modern dam development project, as well as the history of that particular region, in order to evaluate whether or not a dam is the ideal solution for economic growth in a rural society.

Supporters of large dams advocate for continued construction and operation because dams promote international economic development, provide flood control, improve irrigation, and generate hydropower. Some proponents of dam construction see the benefits of increased access to electricity as a substantial reason to construct a dam alone. This is a plausible belief because "one advantage of hydro over other forms of electricity generation is that reservoirs can store water during times of low demand and then quickly start generating during the peak hours of electricity use" (McCully 2001, 11). Promoters of large dam projects also indicate that "the dam will reduce ecological damage caused by flooding and downstream sedimentation. Moreover, the air and water pollution caused by the coal fired power plants that would be necessary otherwise will be avoided" (Edmonds 2000, 171). Hydropower offers a relatively clean energy alternative; however, effectiveness of the dam is determined by a variety of factors. While dams can be used for different purposes, like irrigation, water storage, and hydropower, each dam has its own factors that influence water resource development strategies. Some of these factors include "geographical location, climate, population, economic condition, available arable

land and status of agriculture, availability of other natural resources, especially oil and gas, available development alternatives, and above all, the availability of water resources, their spatial and temporal distribution and status of development" (Hasan 2004, 3). These factors demonstrate why particular regions would be more ideal for hydroelectric or irrigation dams compared to others, which may not be as suited for such a large water resource development project.

One of the primary motives for large dam initiatives is economic growth. However, the reasons for implementing such development projects differ among industrialized and developing countries and can be determined by availability of natural resources. For example:

> Countries with abundant water resources as well as oil and gas resources…would be keen to develop their renewable water resources potential for hydropower, irrigation, water supply and recreation or a combination of them depending upon the demand, financial resources at their disposal and the status of development already attained. Such countries may, however, not face any problem in economic development if the program of their WRD is altered or delayed, since the oil and gas resources can make up for any variation in economic growth due to change in WRD program. (Hasan 2004, 3)

Latin American countries that have significant oil reserves may not necessarily depend on renewable water resources for energy, yet when this resource is utilized it can offer a variety of costs and benefits to the region. While large hydroelectric dams produce relatively clean and inexpensive energy, the economic and agricultural consequences of the dam determine its overall quality and effectiveness. The impacts of dams often depend on the reasons for development. One perspective states that: "big dam building efforts were directly linked to … top-down, technocratic, state-directed development model … This statist development strategy prioritized the promotion of economic growth through the intensive exploitation of … vast natural resources" (Khagram 2004, 142). The national government, the main source of funding for such a project, has an economic incentive because they can receive a return on investment due to increased economic activity. Despite the reasoning behind the development of a dam, the

construction often creates new jobs for local people and foreigners. Dams are built to stimulate foreign investment as well as provide employment to domestic and foreign highly skilled engineers and contractors that come to the country to promote economic development in the region. In developing countries, dams stimulate economic growth due to increases in migration, which then supports local businesses and encourages housing development. Before migration can occur, economic goals for a dam, such as structural size and electrical capacity, must be established during the first decision-making and construction stages. For a dam to be considered, the river's role in navigation must be analyzed as well because "a series of small dams creating several reservoirs along tributaries [could] benefit navigation more than one big dam" (Edmonds 2000, 166). The size of the dam can be a deciding factor if its construction will halt navigation and transportation along a busy river. This intricate process involves an array of professionals working together to build and operate such a complex hydropower dam.

Overall, the main objectives for the construction of a large dam are improved economic welfare and sustained access to water resources; these must be understood before determining whether the short and long term impacts are intentional or accidental. Once the goals are identified, one must become familiar with how a dam works and how the construction and operation stages can significantly impact economic and environmental sustainability of a community. Assessing the goals helps to determine the dam's ultimate success.

How a Dam Works

Construction

The construction of a dam is accompanied by environmental and economic changes, such as increased levels of regional employment and immediate harms to animals that live in the river and riparian vegetation. Throughout the construction process, these man-made impacts are influenced by the length of the construction period as well as the efficiency and accuracy of the

working team. Once the agreement has been made that a dam is necessary for irrigation, water storage, or power generation, the team is gathered and construction workers, contractors, and engineers must move to the construction site. Before construction begins housing for the laborers must be established, whether it be through the construction of new facilities or relocation of current residents. Along with infrastructural adjustments there are also environment changes that must take place before construction can officially begin, "the water in the streambed must be diverted or stopped from flowing through the site … a temporary structure to impound the water … must be built or the water must be diverted into another channel or area down-stream from the dam site … The flow of water is closed off at the very last moment" (Holmes 2012). Once the water is diverted and the foundation is built, "the concrete is then poured or pumped in … the dam is raised section by section and lift by lift. Some major dams are built in sections called blocks with keys or inter-locks that link adjacent blocks as well as structural steel connections" (Holmes 2012). While the blocks are being put in place, the construction of a reservoir begins and "the idea is to build a reservoir that, like a bowl, is equally sound around its perimeter. The water is deepest and heaviest at the dam (when the reservoir is near capacity) so the dam and its foundation cannot be a weak point in that perimeter" (Holmes 2012). Filling of the reservoir may begin once a significant portion of the dam is built and "this is done in a highly controlled manner to evaluate the stresses on the dam and observe its early performance. A temporary emergency spillway is constructed if dam building takes more than one construction season" (Holmes 2012). In the final stages of construction, "the other structures that make the dam operational are added as soon as the elevation of their location is reached as the dam rises. The final components are erosion protection on the upstream (water) side of the dam" (Holmes 2012). Overall, dam construction is a complex process that takes time. This gradual

impoundment of a river can greatly affect nearby ecosystems and fisheries and there are different environmental and economic changes that will be addressed associated with the construction period. Nonetheless, after the final stages of construction are complete, operation can begin.

Operation

It is important to recognize that "the beginning of the dam's working life was also carefully scheduled as a design item, so that water is available in the reservoir as soon as the supply system is ready to pump and pipe it downstream" (Holmes 2012). With this, time is not wasted and ecosystems have the potential to be maintained. Throughout operation "routine maintenance, rehabilitation, safety checks, instrument monitoring, and detailed observation will continue and is mandated by law as long as the dam exists" (Holmes 2012). Although there are required maintenance routines in hopes of ensuring long-term productivity, some jobs tend to be lost once construction is complete and operation has begun. While dams have the goal to promote economic growth, it can come in waves. Along with economic impacts there are complementary environmental harms, and it is not necessarily the responsibility of the dam site staff to encourage downstream and upstream environmental protection, but rather to ensure effective electricity generation.

When is a Dam Effective?

A dam can be considered effective and successful when it meets a variety of criteria. According to the Word Commission on Dams (WCD):

> The end of any dam project must be the **sustainable improvement of human welfare**. This means a significant advance of human development on a basis that is economically viable, socially equitable, and environmentally sustainable … The issues all relate to what the dam will do to river flow, to rights of access to water and river resources, to whether it will uproot existing human settlements, disrupt the culture and sources of livelihood of local communities and deplete and degrade environmental resources. (WCD 2000, 2)

To determine the effectiveness of an international water project, such as a large hydropower dam, one must evaluate its impact on humans and the environment as well as its functionality.

Impacts of Dams

Patrick McCully, author of *Silenced Rivers*, states "more than three–quarters of 49 projects assessed in a 1990 World Bank study of hydropower construction costs were found to have experienced unexpected geological problems of some kind. The study concluded that for hydrodams 'the absence of geological problems should be treated as the exception rather than the norm'" (McCully 1996, 102). If scholars can accept that there will inevitably be some form of environmental harm associated with dam construction, development analysis will be able to determine whether a large hydropower dam can be deemed effective. With this, the geological and economic issues that can result from hydropower construction must be evaluated. Some of the key reasons for dam construction are flood control, power generation, economic growth, and water supplies regulation. These motives can benefit human welfare, as well as result in dam-related costs for nearby watershed communities. I will briefly assess these effects, in addition to displacement and environmental consequences, and describe a select number of their costs and benefits to society. As I evaluate the communities along the Paraná River and the Pilcomayo River, I will revisit these factors and explore the overall impact on community well-being.

Environmental Consequences

There are significant environmental changes associated with dam construction. Such impacts can be organized according to long-term and short-term, as well as upstream and downstream. The environment is impacted in stages starting with construction and followed by operation, and these can be identified by:

> 1. First-order impacts that involve the physical, chemical, and geomorphological consequences of blocking a river and altering the natural distribution and timing of streamflow; 2. Second-order impacts that involve changes in primary biological

> productivity of ecosystems including effects on riverine and riparian plant-life and on downstream habitat such as wetlands; or 3. Third-order impacts that involve alterations to fauna (such as fish) caused by a first-order effect (such as blocking migration) or a second-order effect (such as decrease in the availability of plankton). (WCD 2000, 74)

Environmental impacts of dam construction and operation are related in a sense that the severity of the first stage impacts affects second stage environmental problems. Sedimentation, primarily influenced by first-order impacts and changes in streamflow, is considered one of the main problems associated with dams. Upstream from a dam, "as the sediments accumulate in the reservoir … the dam gradually loses its ability to store water for the purposes for which it was built. Every reservoir loses storage to sedimentation" (McCully 1996, 107). In addition, changes in water temperature and quality due to increases and decreases in the water levels of the reservoir and downstream rivers greatly impact the sustainability of both water and land ecosystems. Dam construction and operation, changes in water levels upstream and downstream as a result of flooding, and fluctuations in demand for electricity influence agriculture as well.

Hydrological Impacts

When it comes to flood protection and flood control, the final results of large water resource development projects are not known until operation is underway. In particular, "the dam's likely impact on other flood-related aspects is not clear, such as how much flooding upstream will be increased… and to what degree flood prevention capabilities will be sacrificed to ensure hydro-generation and navigation capabilities. Flood retention requires empty capacity in the reservoir, while power generation is most efficient with water at the highest level" (Edmonds 2000, 165). Flooding is a controversial issue because dam regulation companies must weigh the costs and benefits of raising the water levels and flooding local regions in order to increase power generation, or reducing water levels in hopes of preserving nearby ecosystems.

On the other hand, many regions without adequate water regulation suffer from natural flooding, which could potentially be prevented with the implementation of a dam.

Displacement

Construction of a dam and reservoir results in an increase of displaced persons who are often forced to change professions, search for new arable land, and separate from family members. While international organizations supporting the development project can provide compensation packages to the resettled communities, in many locations, living conditions tend to worsen and the economic stress causes more harm in the long run. For example:

> Resettlement programmes have predominantly focused on the process of physical relocation rather than the economic and social development of the displaced... The result has been the impoverishment of a majority of resettlers… The loss of economic power with the breakdown of complex livelihood systems results in a temporary or permanent, often irreversible decline in living standards, leading to marginalization. (WCD 2000, 103)

Large dam projects often sacrifice long-term costs for immediate benefits. Displacement can occur during both the long-term and short-term resulting from intentional and accidental, upstream and downstream flooding during the initial startup and operation stages of a dam.

Power Generation

One of the main reasons for the construction of a large hydropower dam is energy production. Hydropower provides an efficient, clean source of electricity that is often desired where air pollution is high. Ultimately, "without dams there would be insufficient food to feed the world's people and energy would be generated by burning fossil fuels that produce greenhouse gases" (Acreman 2000, 1). Hydropower is often promoted because "it is generally inexpensive, requires less maintenance and shutdowns, uses a renewable resource in water, doesn't produce air pollution or radioactive waste, and is extremely flexible since it can be used to meet either continuous baseload or periodic peaking power needs …[and] represents a

substantial project benefit and revenue source" (Platt 2003, 35). In addition, power generation determines the project's economic viability and whether it is worth the potential environmental or social harm. When large dams are able to meet domestic energy needs, economic growth is possible simply because:

> Hydropower has upsides in that 1.6 billion people lack access to electricity, and multipurpose hydropower investments can bring substantial benefits to developing countries in several dimensions (e.g., carbon-free energy, water management, regional integration)… [However] Hydropower's downsides include ecological risks, compromised landscapes, resettlement costs, and detrimental impact on fish migration (Nilsson et al. 2005). (Johansson and Kriström 2011, 233)

While dams provide access to energy and bring economic advantages to developing regions, a dam is not able to reach full capacity immediately. In contrast, ecosystems and communities impacted by the dam are environmentally and socially harmed as soon as construction begins. Specifically, "power will have to be transmitted over great distances to reach the energy-hungry [regions]. The long lead time before generation means that the dam will not be able to solve immediate hydropower [needs]" (Edmonds 2000, 166). An underlying question is whether immediate environmental changes and social harms, like displacement, are worth the potential for long-term economic gain.

To determine the effectiveness of a dam and the necessity of a water resource development project, one must evaluate it using both long-term and short-term criteria. That includes analyzing its potential for a "sustainable improvement of human welfare" with consideration for economic growth, power generation, navigation, environmental changes (i.e. sedimentation and erosion, agriculture, and fishing), flooding, and displacement of persons (WCD 2000, 2). To assess the effects of dams, this thesis compares a river that was dammed (the Paraná River, via the Yacyretá Dam) with an otherwise-similar river (the Pilcomayo River) that

was not, analyzing a concise list of criteria for each, including economic growth, environmental degradation, flooding, and the displacement of society.

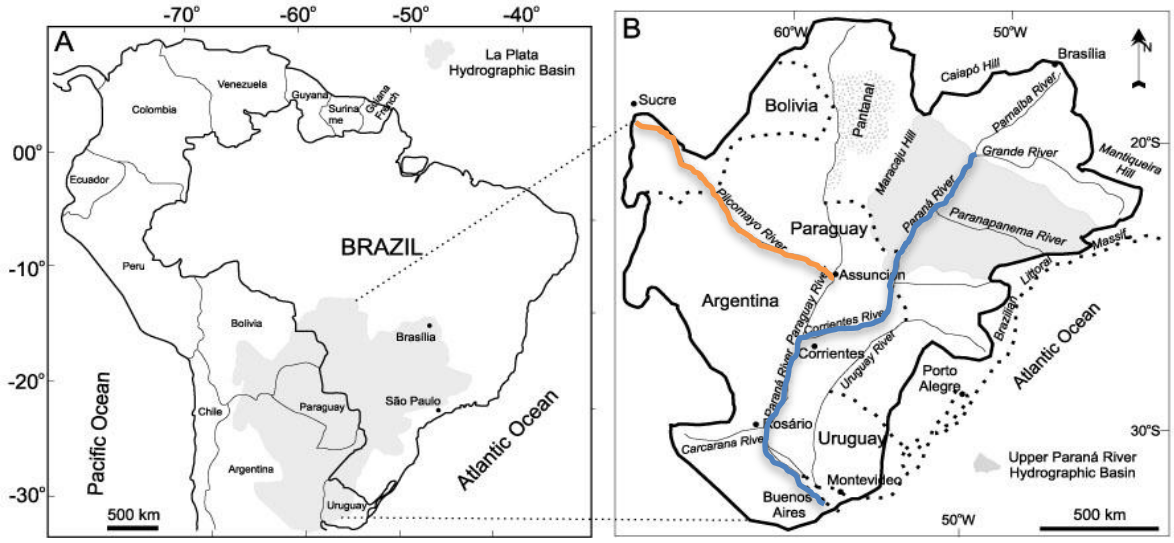
Chapter 2: Life Without a Dam

Life without a dam is not perfect; there are still environmental and agricultural problems that can impact the economic stability of a region despite the lack of a large water resource development project, such as the Yacyretá Dam. In order to look at the livelihood of a community affected by a dam, we need a real sense of what the world looks like otherwise.

Why These Two Rivers?

The Paraná River and the Pilcomayo River are two key waterways that border northern Argentina with Paraguay, Brazil, and Bolivia. These international waterways provide transportation, water for drinking and cleaning, and a source of food for millions of people throughout Latin America and the management, or lack thereof, of these two rivers determines whether there may be a "sustainable improvement of human welfare" (WCD 2000, 2).

Figure 2.1 *The La Plata Basin in South*



This is a unique case study because it assesses two rivers in Argentina, a "countr[y] with abundant water resources as well as oil and gas resources" (Hasan 2004, 3). It is important to recognize that although numerous communities depend on these rivers, there are other means of receiving energy and economic growth through oil and gas resources. The majority of the population in Northern Argentina relies on the Pilcomayo River and Paraná River, both essential waterways in the La Plata Basin (Figure 2.1) and is greatly influenced by many of the same environmental elements such as sedimentation, fishing resources, and agricultural issues. In particular, "the expansion of the agricultural frontier [has] contributed during the last decades to alter La Plata Basin environment and create ongoing problems, such as erosion of productive land, silting of waterways and reservoirs, soil and water pollution, and loss of habitat for fish and wildlife" (Pochat 2010, 2). Considering that the Pilcomayo River and the Paraná River have experienced similar environmental hardship due to an agricultural boom in the La Plata Basin region, it can be assumed that without the construction of the Yacyretá Dam, the two rivers would have stayed on the same general environmental path.

In addition to man-made agricultural influences, the communities along the Pilcomayo River—specifically in the Argentine province of Formosa, and those that reside in Posadas, Misiones, and Ituzaingó, near the Yacyretá Dam— had once lived similar lives economically and agriculturally because these northern communities are accustomed to the same general climate and natural weather patterns. In Misiones, near the Yacyretá dam, the province is characterized by a humid subtropical climate. Similarly, along the Pilcomayo River in Formosa, "the climate … has tropical to subtropical climatic conditions … [and] is differentiated more from east to west than north to south" (Formosa.gob.ar). In the Pilcomayo River Basin, "forests alternating - on the levees of rivers and streams assets - with the semi-flooded grassland of the interfluves.

The lands are dedicated to the use of natural grasslands, with agriculture at the center of this region" (Formosa.gob.ar). Intensive agriculture is discouraged in Misiones due to high levels of erosion and heavy rainfall, similar to the Upper Pilcomayo (Figure 4.1). However, "Misiones is an important producer of yerba mate… as well as tobacco, tea, wood, citrus fruits and vegetables… The tobacco sector is made of smallholding farmers" (En.argentina.ar 2008). In relation to the Pilcomayo River Basin, farmers that depend on the water from the Paraná are impacted by natural weather patterns and anthropogenic changes in water quality. Although the Pilcomayo River and the Paraná River are utilized by poorer communities relative to the rest of Argentina, the Paraná River—a slightly longer body of water with more rapids, located closer to Brazil and Buenos Aires—had the capacity to produce large amounts of energy for many people.

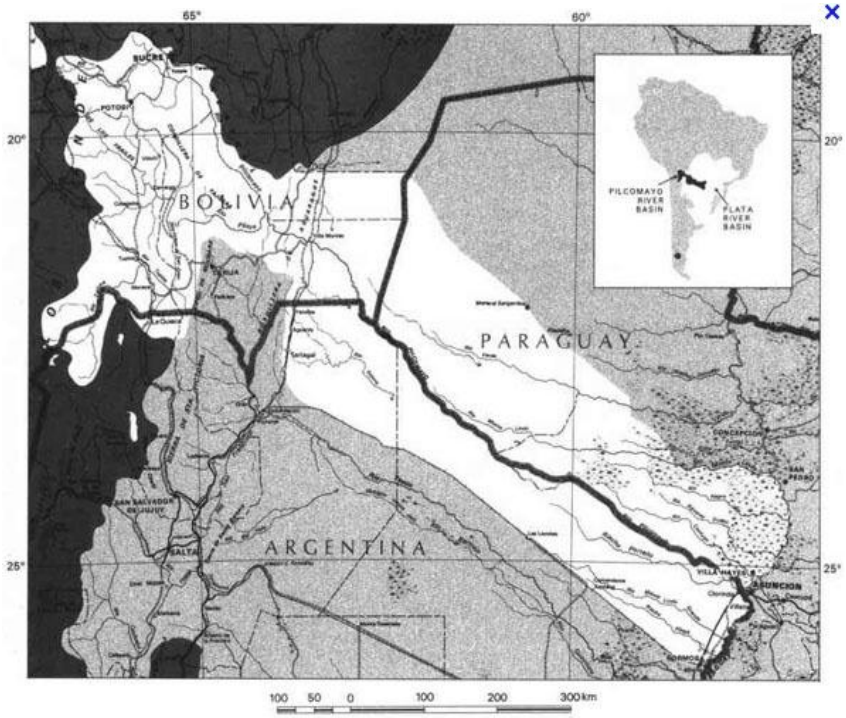
The Pilcomayo and the Paraná River have served as beneficial waterways before and after the construction of the Yacyretá Dam; however, over time more and more water resource development projects were implemented along the Paraná in hopes of stimulating economic growth and providing more efficient irrigation. In Misiones, before construction of the dam began "some visitors observed that the lack of good water supplies could be one of the factors inhibiting the development of agriculture in the Posadas surroundings" (Ferradás 1998, 68). This lack of stable water supplies is a clear indicator that the Paraná River, bordering the city of Posadas, was once in the same state as the Pilcomayo in terms of access to clean water. Insufficient water supplies generated from the Pilcomayo River are especially an issue because of high levels of water pollution. Although there were similarities before the construction of the Yacyretá Dam, as water regulation increased for one, the other remained in its natural state. In consequence, there are benefits and costs associated with leaving a river to run its natural course.

The Pilcomayo River: Not dammed

A natural river unobstructed by water resource management projects has several benefits

that enable communities that depend on it to flourish without the need to enforce water regulation. For example, the Pilcomayo River (Figure 2.2) is "a tributary to the large La Plata system and has a basin area of *c.* 98 000 km². The river arises in the Bolivian Andes … and cuts down through the Andes … until it reaches the Chaco plain near the town of Villa Montes …The river then flows southward through the Chaco, where it forms the frontier between Argentina and Paraguay before it joins the Paraguay river just north of the town of Asunción" (Smolders et al. 2004, 415). The Pilcomayo River Basin is "one of the few intact natural river systems left on the South American continent" (Smolders et al. 2004, 415). Without dams, the Pilcomayo River and its residents greatly depend on annual rainfall. The Pilcomayo River relies on the "river ecosystems [that] are adapted to the natural hydrological regime and many components of those systems rely on floods for the exchange, not just of water, but also energy, nutrients, sediments and organisms" (Acreman 2000, 10). The natural ecosystem in the Pilcomayo River Basin

Figure 2.2 *The Pilcomayo River Basin*



Location of the Pilcomayo River Basin, Argentina, Bolivia and Paraguay

provides its inhabitants with a variety of fish species for food, rich biodiversity, and a vital floodplain.

Challenges of Not Damming

The Upper Pilcomayo has slightly different characteristics compared to the Lower Pilcomayo because they become separated during the dry season. Also, "downstream of the town of Maria Cristina the Pilcomayo River channel is completely filled and covered with vegetation" (Gobierno de la Provincia de Formosa 2012). This lack of stable river flow has contributed to the ever-present economic hardship in the region not only because fish are unable to migrate during the dry season, but also important crops are flooded during the wet season. The Upper Pilcomayo, "consist[s] of unconsolidated sediments that were deposited and transported. This causes the overflowing of the river and the permanent elevation of its riverbed by the deposition of transported sediments … year after year, numerous wetlands, estuaries and lagoons, as well as diverse riverbeds, have disappeared as a result of the renewal and accumulation of sediment" (Gobierno de la Provincia de Formosa 2012). On the other hand, the Lower Pilcomayo "has a well-defined channel, lower flow and is much more stable. It carries little sediment and drains runoff water only" (Gobierno de la Provincia de Formosa 2012). The variations of ecosystems and water flow along the Pilcomayo contribute to the lack of agricultural sustainability of the region. Inconsistent, and often unpredictable, changes in water levels hinder the ability for residents of Formosa to rely on agricultural markets, which can reduce the potential economic gain from the river's resources and the nutrient land.

Lack of water regulation has not only caused irregular water flow, but has also led to the increase of pollution in the Pilcomayo River due to the mining industry on the Pilcomayo River's upper basin, Potosí. Specifically, "the headwaters of the Río Pilcomayo drain the Cerro Rico de Potosí precious metal-polymetallic tin deposits of southern Bolivia. Mining of these deposits has

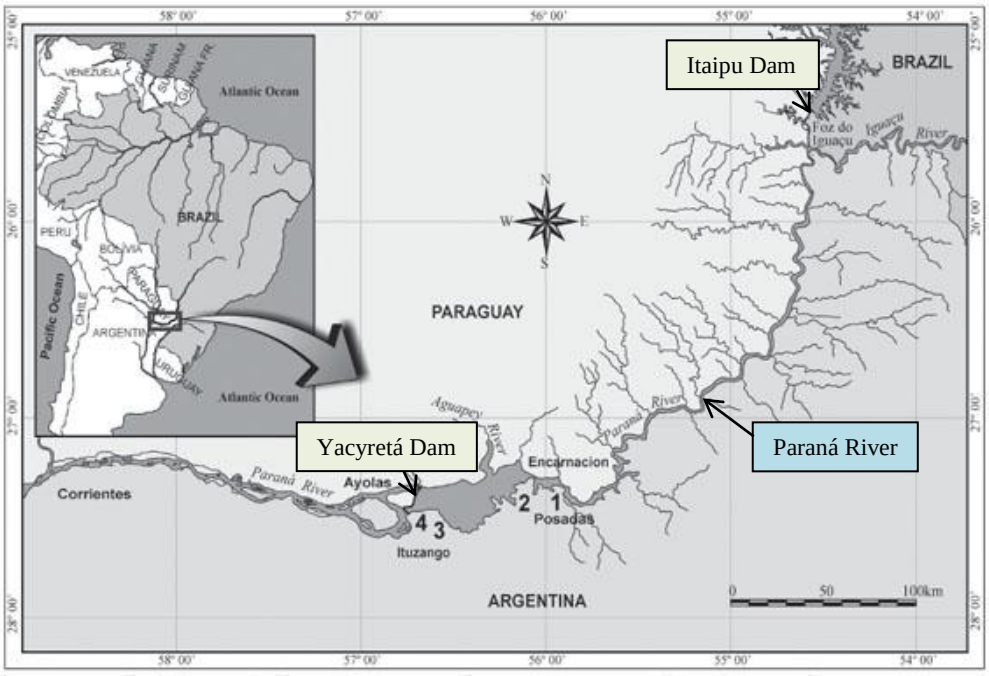
taken place for around 500 years, leading to severe contamination of the Pilcomayo's waters and sediments for at least 200 km downstream" (Archer et al. 2005). Continuous pollution and unreliable access to clean water has hindered development in the region because these "communities living downstream of the mines and processing mills rely on the river water for irrigation, washing and occasionally, cooking and drinking" (Archer et al. 2005). Pollution also has a major impact on the river's numerous fish species, which serve as a vital food resource. In summary, "pollution threatens surface and ground water sources and may make them unfit for many uses … Pollution is especially serious where ground water resources are overexploited and suffer from reduced natural rates of recharge due to deforestation, land use changes and urbanization" (WCD 2000, 7). As a result, pollution throughout the Pilcomayo River has caused problems for economic growth because it harms fisheries and agriculture. Despite the obstacles that come with depending on a river system that lacks water regulation, there are a wide variety of social and environmental benefits, including the simple pleasure of being able to enjoy the natural beauty of the river and taking advantage of the rich biodiversity and natural floodplains.

The Paraná River and the Yacyretá Dam

The Paraná River runs through the Argentine province, Misiones, where "tourism, agribusiness and its associated services are the main sources of income, mainly oriented to forestry and the production of industrial crops (tobacco, yerba mate, tea) with some level of local industrialization" (Nardi 2011, 74). Operation of the first Paraná River dam, Itaipú, began in 1982, and was then followed by the Yacyretá Dam in 1994 for which construction started in 1977 (See Figure 2.3). According to the World Bank, "the objectives of the Yacyretá Hydroelectric Project [were] to provide least-cost base-load electric energy, to improve navigation on the Paraná River, to facilitate future irrigation projects in both Argentine and Paraguayan territories, and to develop fishery" (World Bank 2000). Although these were

considered sincere intentions during the initial decision-making stages of the dam, throughout the construction process, "no fixed method [had] been established for communicating with local people about new projects" (Hasan 2004, 2).

Figure 2.3 *The Paraná River and the Yacyretá Dam*



The Yacyretá Dam had an unstable political and financial foundation to begin with; "an Agreement to build it, signed jointly by Presidents Juan Domingo Peron and Stroessner in 1973, envisaged 20 turbines generating a total of 2760 MW… the project received much of its loans, totaling some $4 billion, from the World Bank and the Inter-American Development Bank … [and] it was continually interrupted by civil war and military dictatorship in Argentina" (Thomas 1993, 54). This development effort was implemented as a result of the conflict between General Stroessner's dictatorship ideals and Paraguay's journey to democracy. The transition from Juan Perón's democratic regime to the military dictatorship can also be considered a key instigator of conflict and obstacles during Yacyretá development (Ribeiro 1994, 48). While the financial and

governmental challenges are crucial to Argentina's economic and social history, the environmental and economic impacts of the Yacyretá Dam are considered independent of these factors in this case study.

In conclusion, Argentina and Paraguay chose to construct the Yacyretá Dam on the Paraná River and signed the Yacyretá Treaty in 1973 in the hopes of stimulating economic growth and generating large amounts of electricity to meet increased energy demands throughout Argentina, specifically in greater Buenos Aires. Construction of the projects' infrastructure lasted from 1978-1983 and this period resulted in a significant influx of migrant workers to the region (Ribeiro 1994, 94). As of 2006, this hydropower dam had yet to meet full capacity of energy production but had the potential to do so (NY Times: Argentina 2006). The debate revolves around the ultimate necessity of the dam and whether it has caused more harm than good in the long run. Due to the natural and man-made environmental problems along the Pilcomayo River, it should be acknowledged that life without a dam is not perfect and that there are other variables, such as pollution and natural weather patterns, which affect economic growth and sustainability of human welfare. To continue the comparison of the undammed Pilcomayo River in the Formosa province and the dammed Paraná River in Misiones, I will address the economic well-being of the residents of Formosa and analyze the economic costs and benefits associated with the construction and operation of the Yacyretá Dam along the Paraná. The identified economic factors also significantly influence ecosystem and agricultural sustainability; therefore, an environmental comparison will follow.

Chapter 3: An Economic Comparison

The economic conditions in Formosa, along the Pilcomayo River, and in Misiones, along the Paraná, prior to the construction of the Yacyretá dam were relatively similar due to the financial volatility in the country. Although Misiones received more tourists and economic traffic, because the Paraná River borders Argentina, Paraguay, and Brazil in the same location, the Pilcomayo River and the Paraná River were once on the same path toward economic instability. Employment near the Pilcomayo River and the Paraná River is influenced by the flow and productivity of the rivers as well as seasonal rainfall, and when national financial insecurity jeopardizes the well-being of agricultural and fishing industries, a variety of economic consequences emerge.

Pilcomayo: State of Nature

The river is "predominantly located within the province of Formosa, one of the poorest in the country…The livelihood of the *aborígenes* of this area, Wichís and Tobas, is based on foraging and fishing in the Pilcomayo, seasonal wage labour, various forms of petty commodity production…and [they] currently live in poverty as small cattle herders" (Gordillo 1999, 4). The economic instability of the Formosa province in Argentina reflects that of the entire country. "Located on the northern border, Formosa has only 450,000 inhabitants and contributes a pittance to overall GDP. Yet its 30 provincial legislators each collect a whopping $12,000 a month in salary … the federal government bankrolls such excesses by financing up to 90% of Formosa's budget" (Goodman 2001). Because Formosa receives significant funds from the Argentine government, it is substantially affected by national debt. Residents along the Paraná River in Misiones, also impacted by national debt, must adapt to improved access to electricity, construction-related economic impacts, changes in employment levels, and finally, displacement and relocation programs.

Energy and Electricity Generation

The electricity generated by a dam can either be directed to downstream communities or to other parts of the nation and neighboring countries. As a result, the production of electricity and subsequent economic gain are big draws for governments that are considering the implementation of large water resource development projects. Yet, there are consequences that come with such gains. Many water development committees are not simply looking to produce clean energy, but to also gain significant economic profit with disregard for negative consequences, like displacement. Similarly, "it has been long noted that investments on these projects are made with only one purpose in mind: energy production. The rest of the objectives are for public consumption; they aim at legitimizing dam construction through portraying it as something that contributes to the common good" (Ferradás 1998, 68). While there are benefits to the communities impacted by dam construction and water regulation, government organizations and company officials often fail to inform those affected about the negative implications.

There have been a variety of conflicts surrounding hydropower distribution between neighboring countries as well as economically unequal cities in Argentina and Paraguay. The energy-based relationship between Argentina, Brazil, and Paraguay has provided a significant economic link that allows each country to feed off the others' gains and feel the downfalls as well. For example, "an early point of contention between Paraguay and Argentina was the percentage of each country's land that would be flooded for the project's dam … Yacyretá's electricity per unit would be more expensive to generate … and the unit price Paraguay would eventually receive was expected to be much greater" (Hanratty and Meditz 1988). In addition, "none of the electricity produced by Yacyretá was intended for use by Paraguayans; it was to be sold back to a binational body that would manage the plant" (Hanratty and Meditz 1988). Due to the fact that the electricity was to be directed elsewhere, Paraguay ultimately received fewer

economic advantages despite the benefits generated from the construction of the dam itself. The negative relationship that Argentina and Paraguay have established throughout the construction and operation process of the Yacyretá Dam is an example of an additional drawback associated with power generation. Overall, the communities that utilize electricity generated by hydropower dams benefit from the increased energy access; however, one cannot disregard the financial costs of dam construction that have significantly contributed to the ever-increasing debt of Argentina.

Construction and Start-up

The Yacyretá Dam has directly affected the Paraná River and its inhabitants east of the Pilcomayo River. Residents along the Paraná fall victim to economic hardship similar to that of the Pilcomayo but also benefit from the increase in economic activity in the region. In comparison to the economy that revolves around the Pilcomayo River resources, residents of Ituzaingó and Posadas rely on the Paraná River and are economically impacted by the construction of the Yacyretá Dam and its reservoir.

Initially, "Yacyretá [was] advertised as a multipurpose project. Its benefits, [the Entidad Binacional Yacyreta] EBY maintains, 'go beyond the use of electrical power: it will facilitate navigation, tourism and irrigation.' It promises that 'the settlement of new populations and industries invigorate a largely forgotten zone of the Rio de la Plata Basin'" (Ferradás 1998, 67). Besides benefits to employment, navigation is also an important factor when analyzing short-term economic impacts because it is argued that the initial "construction will cause so much havoc with navigation in the short and medium terms that it will render any long-term benefits uneconomic" (Edmonds 2000, 166). Although the construction period was presumed to cause problems for navigation, therefore affecting nearby ports, the project still continued because the long-term gains would outweigh this temporary setback. Prior to its construction in 1973, according to a local Argentine newspaper, *Democracia*, Yacyretá was perceived as an ideal

option for economic growth. During this time period, compared to the progress being made in Brazil in the Rio de la Plata Basin on the Itaipú-Corpus project:

> There is only one way of asserting Argentina's presence in the same way: building the Yaciretá-Apipé complex ... It's time to realize that … the Corpus project, should not be continued as an alternative or exclusive of Yaciretá-Apipé, on the contrary, the latter should be a priority ... Actually, if Argentina adopts a more proactive attitude, Brazil could come before the international lending agencies to finalize the funding of the work. (*Democracia* 1973)

Overall due to the capacity for success, the construction of the Yacyretá Dam needed to be a priority in order to receive international support both financially and socially. The dam should be constructed in addition to, not in place of, nearby dams like Itaipú, as a means of increasing economic prosperity. EBY and the Yacyretá Dam strive to meet energy needs throughout Argentina and one of the main concerns during the construction process was how resources would be used and how financial costs and gains would be allocated. According to the Executive Director of the EBY:

> The completion of the Yacyretá projects implies the mobilization of resources… 'Part of the resources will be used to purchase the expropriated real estate that will be employed for construction purposes as well as for the filling of the reservoir. At the same time, we are developing specific initiatives to ensure that the resources generated by the project remain within the region and can be used in activities related to industry, trade and tourism,' Mr. Thomas points out. (NY Times: Argentina 2006)

Ultimately, prior to completion of the dam, Yacyretá had appeared to be the ideal way to promote economic and energy growth in the region because benefits were intended to stay local.

Employment & Short-Term Economic Impacts

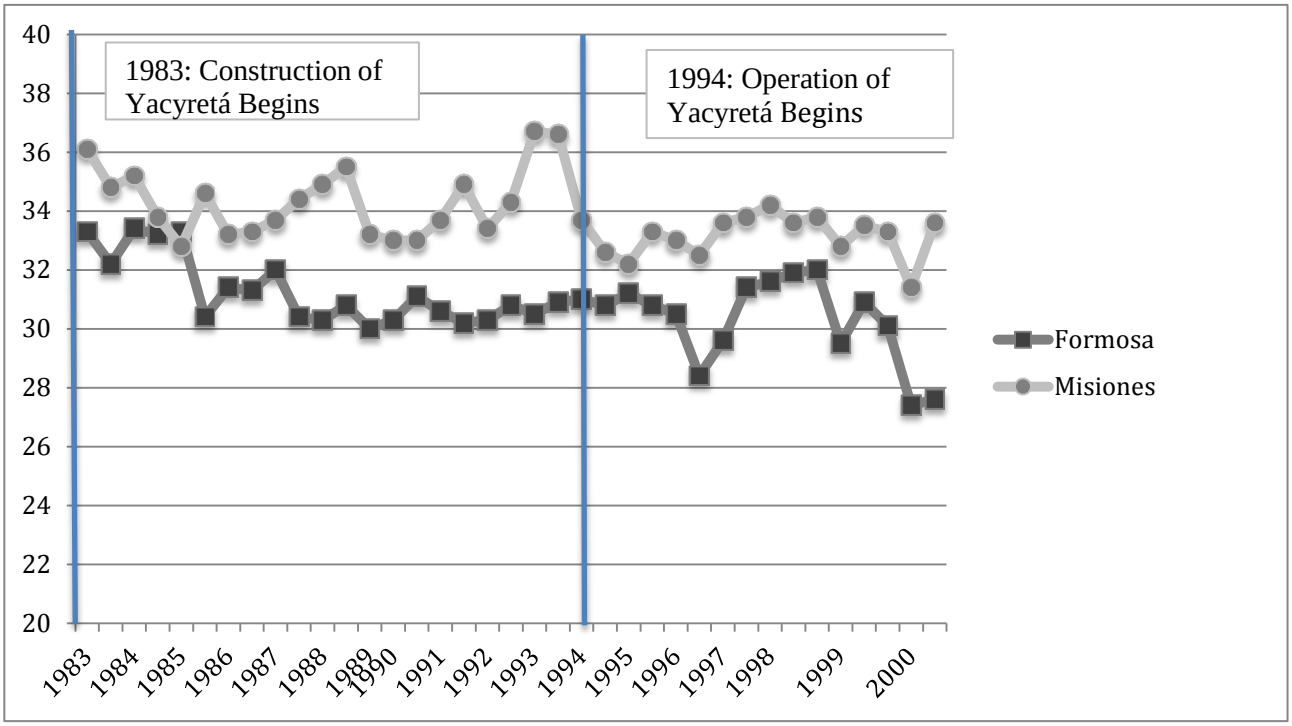
Economic impacts of the Yacyretá dam revolved around the job market and both foreign and domestic employment levels. The construction in particular instigated additional economic changes for the residents of Posadas, Misiones. For example, "the initial stages of the project attracted a considerable amount of migrant labor that came to look for construction jobs or to participate in the economic boom that is supposed to accompany any large-scale project … small

entrepreneurs made investments in the service sector, rents sky-rocketed, and a minilocalized inflation arose" (Ribeiro 1994, 95). Also, "during the peak years of construction of civil works, thousands of workers, technicians, and professionals moved to the encampments in Ituzaingó and Ayolas" (Ferradás 1998, 60). A significant increase in jobs resulted in numerous housing projects near the construction site, especially for contractors and laborers.

The housing infrastructure for employees attracted an influx of migrant workers that would often take away jobs from local laborers. In addition, local Argentines did not receive many of the benefits that migrant labors had obtained. In Ituzaingó for example, "the local population was not allowed in the neighborhoods built for the EBY staff and for the contractor's employees. Fences separated the original town from the new buildings" (Ferradás 1998, 66). This economic divide resulted in an increase in dissent toward the dam and all those involved in the project. Moreover, "the EBY had its own special services which scrutinized visitors and investigated employees before and after being hired" (Ferradás 1998, 66). The increase in migration to the cities closest to the construction site profited local businesses because there were more people to buy basic goods and services. These short-term benefits to the nearby communities sparked economic growth. As demonstrated in the Figure 3.1, Misiones (surrounding the Paraná River) and Formosa (surrounding the Pilcomayo River) were on a similar path in terms of unemployment rate in respect to population; however, as construction progressed on the Yacyretá Dam project, employment increased in Misiones and decreased in Formosa. The growth in economic activity and job availability in Misiones as a result of the dam, contributed to a sustainable increase in human welfare for residents near the Paraná River and the construction site. Similarly, as the construction phase of the project was coming to an end, employment increased dramatically in an effort to complete the dam on time. Nonetheless as the

construction stage ended, employment in Misiones returned to a similar employment pattern found in Formosa.

Figure 3.1 *Trends in Employment Rate (Misiones & Formosa, ARG)*



In summary, beneficiaries of the Yacyretá dam experienced significant job growth and economic gain during the construction period contributing to a "sustainable improvement of human welfare" for those affected (WCD 2000, 2). The decade of job growth presents a significant period of economic stability for the residents of Misiones. Even after the completion of the Yacyretá Dam, benefits are sustained. These economic advantages ultimately support the reasons why proponents of dams think the way they do. Inconsistent economic stability and lack of job growth in Formosa along the Pilcomayo River demonstrate that this potential gain may outweigh implicit and explicit costs associated with dam construction and operation.

Construction Benefits

Construction not only provided jobs for both domestic and foreign laborers, but also enabled economic growth in neighboring countries such as Paraguay. Some beneficiaries of the Yacyretá Dam project were from Paraguay and in the late 1980s, the construction of the Yacyretá Dam:

> Was expected to give a boost to the Paraguayan economy…the Argentine-Paraguayan project would provide renewed construction jobs, large capital inflows, and eventually badly needed foreign exchange revenues. The binational project also would provide seriously needed bridges, highways, improved river transport at the port of Encarnación, and even increased irrigation potential for nearby rice fields. (Hanratty and Meditz 1988)

The variety of economic gains for the Paraguayans, such as job growth and infrastructure development, demonstrates the economic viability of the Yacyretá Dam upon initial construction. The overall development in roads improved transportation between countries, as well as nearby cities, making tourism more practical and the transfer of goods easier. These benefits of construction demonstrate that the implementation of the Yacyretá Dam brought a "sustainable improvement of human welfare" to riverside residents of Paraguay (WCD 2000, 2). However, the gains to employment must be considered alongside the consequences of displacement.

Short-Term Displacement: Construction of the Dam and Reservoir

Displacement, due to the construction of a dam and its reservoir, is one of the first physical impacts, which affects the ability to attain sustainable development. Although displacement often occurs as a result of natural disasters, it is clear that when displacement can be controlled, the effort must be made to reduce its negative corollaries. When constructing a dam, housing is developed for laborers and contractors, which can require locals to be relocated so that those involved with the construction can live closer to the site. Families living in the communities upstream from the planned dam location, near the reservoir, had to be relocated as

well. Immediate relocation and displacement due to the initial construction is a significant cost that must be accounted for when determining whether a dam can provide a "sustainable improvement of human welfare" (WCD 2000, 2). In addition to relocation in the short run, there is substantial displacement that ensues from both natural and intentional flooding as well as other long-term environmental harms that I will elaborate on in Chapter 4. As for now, I will address the economic changes that occurred as soon as construction ended and operation began.

Operation

The Argentine economic benefits of the Yacyretá Dam were not only seen in job growth during the construction stages, but in hydropower generation as well. As of 2006, "Yacyretá is contributing between 14 and 16% of Argentina's total electricity production, but that figure is expected to jump to around 25% when it reaches full thrust" (NY Times: Argentina 2006). Although the dam contributes a substantial percentage of the nation's electricity, the dam has yet to achieve ideal levels of economic development. According to the architect Oscar Alfredo Thomas, Executive Director of the Yacyretá Binational Entity, "it is still not functioning at 100% capacity because we are seven meters below the expected level established in the final project of the reservoir. We are operating at 76 meters above sea level in the Posadas-Encarnación axis" (NY Times: Argentina, 2006). To reach this goal, the EBY would have to increase water levels and, in turn, further inundate nearby Posadaños and residents of Encarnación, Paraguay.

Long-Term Economic Impacts

Over the long run, the Yacyretá Dam affected the economies of more distant regions as well. Specifically in the Iberá Wetlands, the regional economy was greatly impacted by excess water: in Ituzaingó a loss of "about 10,000 heads of cattle per year in herds in the department of Ituzaingó, due to the annual loss of 20–25,000 ha of productive land… even in periods of drought, the water does not recede" (Canziani 2006, 184). Considering that not only nearby

communities are impacted by dams and flooding, but also agricultural communities further downstream, it can be concluded that a dam on the Pilcomayo River could have similar effects on already unstable agriculture. In addition to the long-term economic impacts downstream, many communities near the dam were forced to relocate and suffered from economic hardship.

Relocation Programs

Displacement due to the construction of the Yacyretá Dam and intentional flooding has caused significant socioeconomic changes throughout nearby cities, including Posadas, Misiones and Ituzaingó, Corrientes. It is crucial to understand that "relocation does not only include large sectors of the population, it also includes a significant part of the urban infrastructure on both banks of the river: train stations and railways, ports, sections of highways, public and commercial buildings" (Ferradás 1998, 61). When businesses and public services are eliminated due to relocation, the economic stability of a community is hindered, numerous methods of transportation are damaged and overall productivity of the town decreases.

Resettlement projects are often implemented to make the transition for communities much smoother. However, resettlement projects are not always effective due to "lack of coordination of funds, job provision and decent housing, as well as corruption, misuse of funds, discrimination against rural residents in the allocation of resources, and ill-prepared undercover resettlement" (Edmonds 2000, 169). Despite seemingly good intentions, underrepresented groups tend to suffer from economic hardship, not only related to dam construction, but also from failed relocation projects.

Those displaced by the Yacyretá Dam construction were often financially challenged as a result of its relocation schemes. For example, "one of the Relocation Program goals stated that the relocatees needed to increase their income to be able to meet payment demands" and continue living in the housing facilities (Ferradás 1997, 455). Therefore, education and training

programs were developed to make Posadaños qualified for a variety of jobs that would provide the residents with a substantial income. These programs "transformed the existing unskilled and mostly unemployed labor force into a surplus labor population of skilled or semi-skilled blue-collar and white-collar workers" (Ferradás 1997, 455). The educational projects provided the means to achieve a "sustainable improvement of human welfare" because civilians would from then on have more advanced skills to contribute to the regional economy (WCD 2000, 2). Unfortunately, many cities did not have the physical or financial capital to develop such jobs; "even if they obtained the necessary tools … there [were] not enough employers to hire them or customers to pay for their services" (Ferradás 1997, 455). Although new educational programs had the right motive, one can infer that for overall success such projects would require citywide cooperation and appropriate funding.

A negative aspect of relocation programs is that remunerations were not made available to all communities impacted by flooding. In the Yacyretá Dam case, some families that were aware of relocation programs were unable to take advantage of the benefits because "many families were excluded from EBY's census of affected families, but should have received compensation … while others that EBY admitted to be eligible had never received indemnification" (Switkes 2004). Broken promises and lack of care demonstrated by the EBY challenged any sense of an improvement to the sustainability of human welfare among the residents affected by the Yacyretá Dam. In Paraguay, the displaced were unable to benefit from potential economic growth in the region because "the distance from the resettlement areas to the city of Encarnación made it difficult for many resettled to find work, some having to walk as much as four hours to reach town. Investigators also cited cases of 13-15 year-old girls from the resettlements being forced to work as prostitutes in Encarnación to support their families"

(Switkes 2004). The displacement caused by the construction of the Yacyretá Dam and its reservoir, as well as resulted flooding, hindered the economic growth and stability of the region. Residents of Ituzaingó, Posadas and Encarnación lost dependable land and were forced to find new work. Some of the social impacts of the division were weighted on the local communities that had been promised "electrical power… navigation, tourism and irrigation," and were deprived of many of the benefits given to the migrant workers, like sufficient housing and social services (Ferradás 1998, 67). Along with this social divide, displacement resulted in a disparity in health care.

Health Impacts

As a result of poorly managed relocation programs and a lack of monitoring by the EBY, there was a significant increase in health problems, such as diarrhea, parasites, and skin problems for those impacted by the Yacyretá Dam. Drinking water wells were polluted as a result of the dam as well (Switkes 2004). The resettlement areas for the displaced often lacked substantial medical facilities, plumbing, and clean drinking water (Switkes 2004). However, before scholars can assess changes in living conditions as a result of the dam, the analyst must consider what life was like in Misiones prior to the construction and completion of the dam.

Misiones consists of "a majority urban population residing in intermediate cities and rural populations living in small towns and scattered throughout the countryside" (Nardi 2011, 74). With small towns and an agriculture-based economy, the Misiones communities, as well as those near the Pilcomayo River, do not have access to basic amenities, such as consistent access to clean water and sanitation. As demonstrated in Table 2, the percentage of households with unsatisfied basic needs has decreased since 1980 during the time of the construction of the dam, showing improvement in human welfare for both provinces. After operation began in 1994, it is demonstrated that by 2001 the two provinces had experienced a "sustainable improvement of

human welfare" even though population had increased (WCD 2000, 2).

Table 2 *Percentage of population in households with unsatisfied basic needs (NBI)*

Province (River)	**1980**			**1991**			**2001**		
	Total Pop.	*Pop. with NBI*	*%*	*Total Pop.*	*Pop. with NBI*	*%*	*Total Pop.*	*Pop. with NBI*	*%*
Formosa (Pilcomayo)	292,363	159,072	54.4	396,428	155,072	39.1	484,261	162,862	33.6
Misiones (Paraná)	580,522	263,424	45.4	782,131	262,812	33.6	960,002	260,271	27.1

Source: Instituto Nacional De Estadística y Censos

While the long-term timeline indicates a gain to society, the short-term costs during the early stages of the dam were significant. Near the Yacyretá Dam, "homes along urban creeks flooded every time it rained … [and] flooded-out homeowners [had] received no compensation from EBY. It found many resettlement areas lacking medical facilities, drinking water, adequate plumbing … and found homes to be undersized … there was no plan as to how homes will be linked to the planned sewage treatment center in Encarnación" (Switkes 2004). Ultimately, although there were health impacts of the relocation programs, overall NBI has decreased over time resulting in an improvement of human welfare.

Prior to the completion of the Yacyretá Dam, during 1991 Formosa and the residents of Misiones in greater Posadas had moderately the same availability of sanity services proportional to the population size of the provinces. Table 3 demonstrates, in relative terms, that each region had equal access to drinking water. Also, despite the poor implementation of sanitary services in relocation programs, Formosa and Misiones experienced a similar lack of clean water resources.

Table 3 *Occupied private housing units: households and population surveyed therein, by availability of sanitary services in the housing unit, by urban center.*

Urban center, number of housing units, households and population	**Total**	**Availability of Sanitary Services 1991**			
		Drinking water and sewers	*Only drinking water*	*Only sewers*	*Neither drinking water nor sewers*
Formosa (Pilcomayo)					
Housing Units	32244	43.86%	42.62%	0.17%	8.03%
Households	34486	42.99%	42.9%	0.17%	7.63%
Population Surveyed	146564	41.79%	44.55%	0.19%	7.67%
% of households in pop.	23.53	24.2	22.66	20.99	23.42
Misiones (Paraná)					
Housing Units	50267	21.48%	42.89%	0.19%	30.01%
Households	53220	21.01%	43.13%	0.19%	29.56%
Population Surveyed	208808	20.69%	41.99%	0.20%	31.58%
% of households in pop.	25.49	25.88	26.17	24.16	23.86

Source: *Statistical Yearbook of the Argentine Republic.* Vol. 15. Buenos Aires: Instituto Nacional De Estadística y Censos, 1999, table 3.3.8

Overall, the construction of the Yacyretá Dam instigated economic benefits and social costs in Misiones. The negative impacts of relocation programs on the displaced communities caused a loss in social well-being; however, gains associated with new educational and training programs gave communities hope for long-term economic growth.

A Dam for Pilcomayo? Will it Help *Economically*?

One could argue that the increase in available hydropower produced by the dam and the long-term economic benefits outweigh the costs to the displaced communities of the Yacyretá Dam. But, residents along the Pilcomayo demonstrate that a destructive dam does not have to be the only solution to development. Due to lack of funding and coordination, the Yacyretá team's failure to manage resettlement programs properly with regards to human well-being and equality demonstrates that not all communities may be economically equipped for such a large water resource development project.

Although the Pilcomayo remains one of the only untouched rivers in South America, that does not mean water resource development projects have not been discussed or that regulation is not an option for economic growth. In June of 1977 it was suggested that along the Pilcomayo, "eight proposed hydroelectric facilities… would generate 2,352 MW of electrical power, provide flood and sediment control in the lower basin, and irrigate approximately 180,000 ha" (OAS 1984). Despite these potentially positive impacts, it was concluded in the case study that the implementation of hydroelectric dams on the Pilcomayo River would result in a high increase of exports, a medium increase in national gross product, a low increase in the income of the rural population and minimal equalization of the population (OAS 1984). Although the dam demonstrated that it could potentially bring slight improvements to human welfare, these benefits at that time did not outweigh the long-run and short-run explicit and implicit costs, such as financial and social harm.

A dam for the Pilcomayo River may be economically beneficial to the upstream and downstream inhabitants if those impacted are properly informed about every step of the process. Regions near the Yacyretá Dam that were flooded during dam construction were not promptly informed or educated about the situation. For example, "the EBY … controlled and limited access to the neighborhoods that would be flooded by the dam" (Ferradás 1998, 66). Construction companies and international organizations that were in charge of operation often overlooked small nearby cities that were directly affected by increases in water levels. Some of the failures associated with the construction of Yacyretá involved lack of education to the public indicating exactly how nearby communities would benefit from a large water resource development project. In particular, "when preliminary studies on the hydroelectric project started, EBY's leaflets, press releases, and newspaper articles included the control of floods

among the most important benefits of dam construction…Only in the 1990s did Yacyretá officials admit that the dam would not control major floods" (Ferradás 1998, 105). The lack of necessary education about the project to the affected communities has resulted in resentment toward the dam and ignorance toward its long-term benefits.

The costs and benefits to employment and displacement related to dam construction enable the conclusion that although a community may benefit from an increase in employment levels, the community may also experience the negative consequences of physical and social displacement. The residents of the Pilcomayo River Basin do not have the luxury of benefitting from job growth and improved economic activity that can lead to a "sustainable improvement of human welfare" (WCD 2000, 2). While communities displaced by the construction of the Yacyretá Dam and its reservoir were forced to relocate and search for new work and land, the overall economic gain to the region and access to electricity has the potential to outweigh these costs to society. Even though communities dependent on the Pilcomayo River avoid dam-related relocation, they are still victims of displacement and agricultural instability due to natural causes, such as inundation. Ultimately, the economic benefits, such as employment and power generation, are advantageous to upstream and downstream communities in Misiones, as well as residents of Paraguay. The gains have the potential to be greater than the losses to the relatively smaller communities impacted by flooding and displacement.

Economic Factor	**Formosa (Pilcomayo River)**		**Misiones (Paraná River)**	
	Upstream	*Downstream*	*Upstream*	*Downstream*
Employment	C	C	B	B
Power Generation	C	C	B	B
Flooding & Displacement	C	C	C	C
Displacement & Relocation Programs	N/A	N/A	C/B	C/B

Chapter 4: An Environmental Comparison

Economic benefits and costs associated with dam construction and operation culminate in environmental changes, such as increased waste and energy inefficiency due to poorly built homes designed for large numbers of migrant workers. On the other hand, there are environmental harms related to lack of economic development, such as ineffective water use for agriculture along the Pilcomayo River.

Pilcomayo: State of Nature

In Argentina, the Pilcomayo River and Paraná River inhabitants fall victim to natural and man-made environmental disparities. Communities along the Paraná River suffer from constant environmental changes, such as:

> Increased rainfall associated with the El Niño Southern Oscillation (ENSO), construction and operation of the series of 40 single purpose hydropower projects on the Paraná River, deforestation and conversion to soybeans in response to world market forces leading to serious soil erosion and increased stormflows, and downstream accumulations of sediment. (Biswas et al. 1999, 304)

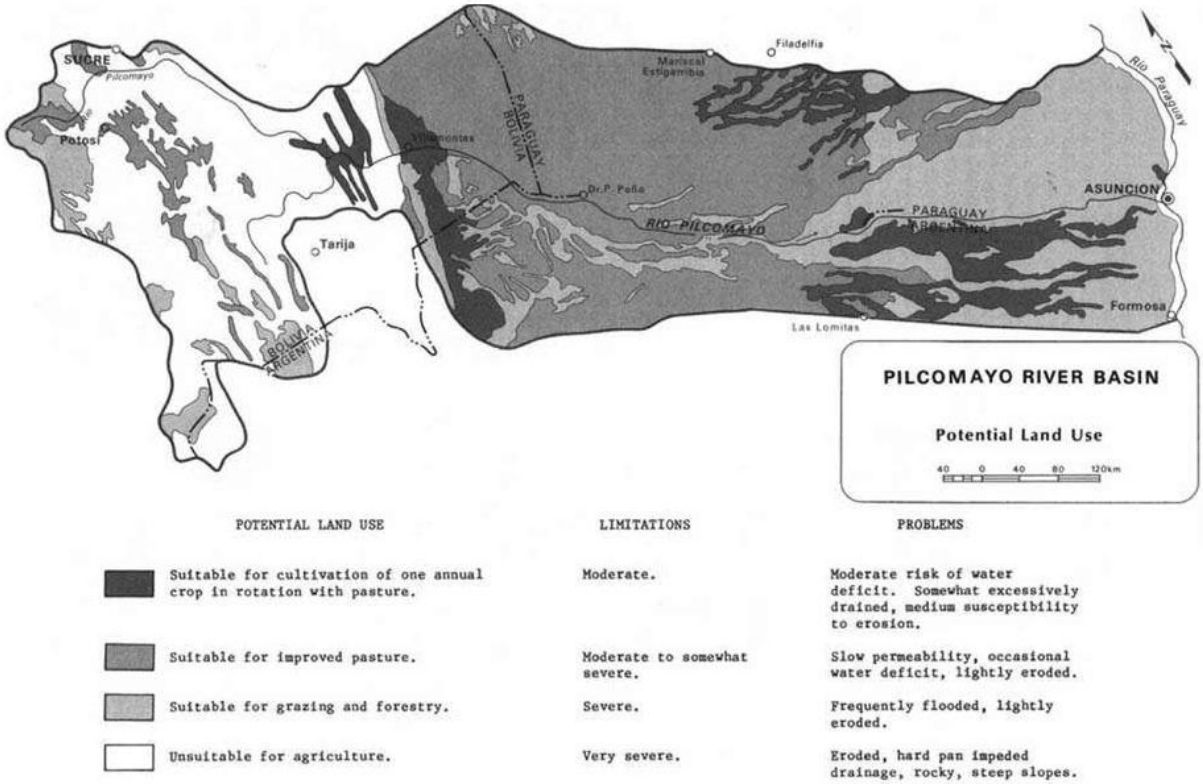
The Pilcomayo River Basin residents must adapt to all of these factors except for the construction and operation of dams: the Pilcomayo River Basin is "one of the few intact natural river systems left on the South American continent" (Smolders et al. 2004, 415). The current natural flows of the river have produced a unique ecosystem. For example, "in the Paraguay–Argentine territory large areas of land are inundated by the river during the rainy season [and] these floodplains serve as important feeding-grounds for many migratory fish species" (Los Amigos del Pilcomayo 2009). The environmental state of the basin plays an important role in the current productivity of the region. The floodplains near the Pilcomayo also "enhance biological productivity by supporting a high rate of plant growth. This helps to maintain biodiversity and the integrity of ecosystem" (Woodriver.org 2012). Along the river there are agricultural benefits of natural floodplains: "wild and cultivated products are harvested in floodplains, which are

enhanced agricultural land made rich by sediment deposits" (Woodriver.org 2012). Despite the agricultural gains from nutrient-rich wetlands, there are costs of leaving the Pilcomayo River to run its natural course. One of the major problems in the Pilcomayo is:

> High erosion rates in the Andean region. The sediment load of the Pilcomayo River is amongst the highest in the world… Although human factors such as agricultural activity, deforestation and the construction of roads have probably enhanced erosion over the last centuries … The main cause of the strong erosion is the susceptibility of the local geological formations to erosion because of their small particle size. (Smolders et al. 2002, 419)

The natural flows of the river and high sedimentation levels contribute to the overall agricultural capacity of the Pilcomayo River Basin. Erosion and sedimentation have negatively impacted the environmental well-being and "the high, largely natural, sediment loads of the river have led to the development of an alluvial fan system, which is still active … [and] the river is currently retracting due to siltation of its bed" (Smolders et al. 2004, 415). High sedimentation levels in the Pilcomayo are negatively impacting the agricultural sustainability of the region and affecting the river's productivity as a result. The problems stemmed from the natural flow of the river have led scholars to believe that, "owing to the variability of the river regime and heavy sedimentation, most uses of the river would require the construction of dams to regulate the river discharge and sedimentation" (OAS 1984). The agricultural capacity along the Pilcomayo River indicated in Figure 4.1 demonstrates that downstream ecosystems, which depend of the rich biodiversity and nutrient soil of the floodplains, are suitable for grazing and improved pasture.

Figure 4.1 *The Pilcomayo River Basin and Potential Land Use*



The middle region of the Pilcomayo River Basin is impacted by occasional water deficit, seen in Figure 4.1. Irregular water levels, as well as sedimentation and erosion, greatly affect the sustainability of Pilcomayo fisheries. Similarly, natural forces like El Niño, as well as increased soy and cattle production, have caused fluctuations in the fish population in the basin. The Pilcomayo River serves as a major food source for locals, and the need for economic prosperity has led to overfishing and contamination of the resource. Despite anthropogenic changes in fish populations, the effects of natural weather patterns are also significant: "in dry years young fish are unable to migrate from the permanent lagoons and pools where they survive the dry season towards the highly nutritious water–land transition zones" (Stassen et al. 2010, 4). Ultimately, the dry seasons affect economic stability, dependent on agriculture and fisheries, because along the Pilcomayo:

> Since the middle of the 20th century, commercial fishery has become more and more important… because the production of ice for storage and the improvement of the roads allowed fish to be transported to other parts of the country. Most fishery activities are located… where the fish migrate into the Andean part of the river and have to face strong water currents, which hamper their progress. Fish traps built along the shoreline made the fisheries very efficient. (Smolders et al. 2004, 415)

Commercial fisheries have developed successfully without large water resource development projects; however, there has been a decrease in catch over time. After research was conducted on the decline of these fish, the reason for catch reduction was determined to be threefold: exploitation by commercial fisheries, a record length El Niño from 1991-95, and increased sedimentation due to erosion during the rainy season (Smolders et al. 2004, 415).

While the residents of the Pilcomayo River Basin must adjust to irregularities in natural weather patterns and high levels of sedimentation, they are not impacted by the construction and operation of a large hydropower dam. These communities have managed to develop relatively successful fisheries that residents have relied on for years. Therefore, I will now explore environmental changes, both positive and negative, associated with the implementation of a modern water resource development project on a river similar to the Pilcomayo that has also been affected by heavy rainfall and natural phenomena such as El Niño.

Construction-related Environmental Problems

Environmental consequences associated with dams are triggered during the initial construction stages. In developing countries, such harms are often exacerbated due to lack of stable infrastructure and regulatory agencies. In summary, "the potential environmental impacts of rural dam construction on water resources are classified into two categories: a. changes in water regimes as a result of dam construction; and b. impacts caused by events during the operation of the dam" (Government of Western Australia WQPN 2006, 3). The majority of

environmental damages caused by dam construction are changes in natural ecosystems, agriculture, water temperature, quality, and nutrient levels.

One of the first physical challenges during dam construction, seen along the Paraná River as a result of the Yacyretá Dam, is "altering the path of a waterway during the construction of dam … (such as diverting the flow around the dam site so that water is not entering the dam during construction). Any loose surface material in the path of the new flow may be carried downstream and contribute to altered flows in the waterway or sedimentation in downstream dams or pools" (Government of Western Australia WQPN 2006, 14). During the initial construction phase when water diversion is necessary, the dam may also create "changes in water movement that … may threaten the ecological values of water dependent ecosystems" (Government of Western Australia WQPN 2006, 14).

Additional environmental issues along the Paraná are related to "the clearing of land to construct the dam [that] could also cause the water table to rise, exacerbating the salinity risk to the dam" (Government of Western Australia WQPN 2006, 14). Land clearing can also increase likelihood of erosion. Companies, such as EBY, responsible for the construction process must be aware that "vegetation around the dam helps to prevent erosion, improve water quality, provide storm protection, retain nutrients and can restrict the growth of nuisance plants and algae. Dam construction can also destroy riparian and wetland vegetation and fauna habitat" (Government of Western Australia WQPN 2006, 14). Nearby ecosystems must be cared for because they contribute natural services, such as water regulation and erosion control.

Ecosystems include both riparian vegetation and animals that live in the river. The early construction stages of the Yacyretá Dam immediately harmed the livelihood of migratory fish simply because "dams constructed on-stream provide a physical barrier for the movement of

aquatic species. This movement might be an essential part of their life cycle, such as an upstream migration to spawn" (Government of Western Australia WQPN 2006, 14). Nonetheless, if construction takes longer than planned and adjustments are not made to conserve biodiversity and water quality, ecosystems can suffer.

Some of the pollution costs of dam construction are produced from "increased turbidity and sedimentation in the waterway resulting from vegetation removal, soil disturbance, and soil rutting … The proximity of dams to streambeds and floodplains increases the need for sensitivity to pollution prevention at the project site in planning and design, as well as during construction" (EPA Section 6217, 1993). Since construction of the Yacyretá Dam took longer than anticipated, total costs increased and the surrounding ecosystems were damaged even further. Nonetheless, construction related environmental problems could be avoided if construction never occurs in the first place. The Pilcomayo River has benefited from its rich biodiversity due to the lack of ecosystem disturbance. After construction-induced environmental problems comes those associated with operation.

Operation-related Environmental Problems

With construction of a dam, startup and operation soon follow. The environmental challenges associated with operation of the Yacyretá Dam include "the potential threat to water resources [such as] … failure of the dam structure, pollution of stored water by contaminants or changes in water quality and subsequent release of this water, and escape of aquatic organisms from the dam" (Government of Western Australia WQPN 2006, 14). The water released from the dam can affect the water quality downstream, especially changes in water temperature and chemical composition, because the water resources from the still reservoir upstream are pushed into a fast moving downstream river.

Upstream from the dam, a reservoir is built and with this comes its own environmental

harms. For example:

> The relatively still waters can act as a trap for nutrients. These nutrients may cause algal blooms within the dam. If nutrient rich water leaves the dam, it can contribute to eutrophication downstream. Nutrients can be introduced to the dam from aquaculture effluent and livestock waste … The still waters of a dam can cause seasonal stratification to occur. This can lead to water temperature changes, particularly during summer, exacerbating water quality problems. (Government of Western Australia WQPN 2006, 15)

Changes in water quality and water temperature can negatively impact the livelihood of fish species, which in turn can influence the economic well-being of both downstream and upstream communities. Despite the short-run environmental impacts caused by the construction and initial operation of the dam, there are significant positive and negative long-term environmental consequences related to irrigation development, adjustments to agriculture, and flooding. Flood control is a highly debated topic because while some floods can be natural and beneficial to an ecosystem, others can be unplanned and deadly.

Flooding

There are three types of flooding to consider when comparing the Pilcomayo River and the Paraná River: natural floods, dam-related intentional floods, and dam-related accidental floods. There is also a significant difference between upstream and downstream flooding in relation to both natural and dam-related floods. When it comes to intentional flooding "a managed flood is a controlled release of water from a reservoir to inundate a specific area of floodplain or river delta downstream to restore and maintain ecological processes and natural resources for dependent livelihoods undertaken in collaboration with stakeholders" (Acreman 2000, i). In some cases, controlled floods are used to manage the damage from a natural flood. Flooding used for ecological and agricultural development is beneficial to communities that rely on such methods for economic prosperity.

Natural Flooding & Displacement Along the Pilcomayo River

The Pilcomayo River Basin, a region susceptible to inundation and drought, suffers from a variety of economic obstacles when it comes to water accessibility. For instance, "dry years not only decrease the availability of food but also result in a lack of connectivity between the elements of the floodplain" hindering consistent agricultural productivity (Smolders et al. 2002, 423). Along the Pilcomayo, "during the flood season, the water spreads over the flatlands under the cacti and dry forest, changing the shape of the land … the river has slowly moved northwards, creating undulating areas of silt left by prior flood" (Alcorn 2012, 166). Communities in the Upper Pilcomayo must deal with flooding during the rainy season—an obstacle that greatly affects agricultural output and revenue. Some of the key debates surrounding this issue deal with the potential for economic growth, economic sustainability, and what is best suited for each community.

Natural floods and weather patterns greatly impact communities that lack water regulation projects, such as those along the Pilcomayo. Residents of the Pilcomayo River region have become accustomed to its natural weather patterns because "the river is strongly influenced by the hydrological cycle, which is driven by the differences in rainfall between the dry (May to October) and the wet (November to April) seasons. The lower reaches are alternately affected by inundation and drought" (Smolders et al. 2004, 415). Local communities have accepted these irregularities as a part of life: "the Indigenous communities value the annual flooding because it renews moisture in the soil, sustains the forest on which Indigenous communities depend, and regenerates the wetlands that support the centuries-old criollo herding system" (Alcorn 2012, 166). Although they appreciate the floods to some extent, the communities that depend on the river and subsequent agriculture are significantly influenced by these unregulated cycles, which often hinder economic improvement. Water resource irregularities along the river have

contributed to numerous conflicts between Argentina and Paraguay, such as during the 1970s and 80s:

> The settlement patterns of *aborígenes* and settlers in northwestern Formosa were severely affected by changes in the course of the Pilcomayo. Given the sedimentation of this river, the marshes in its middle and lower course…began to expand upstream and to overflow the old riverbed…the water began flowing to the southeast of the old course of the river, following a direction that does not coincide with the borderline. As a result, several villages and hamlets in Formosa were flooded and destroyed. (Gordillo 1999, 4)

Unplanned inundation and drought have caused major challenges for the Formosa residents both agriculturally and economically, plus threatened the livelihood of a variety of fish species.

Natural phenomena, such as El Niño Southern Oscillation (ENSO), have impacted the productivity of the Pilcomayo River as well as the livelihood of nearby communities and migratory fish. In particular:

> ENSO can have a strong effect on riverine fish production in floodplains via its effect on river discharge…a relationship exists for migrating fish that have their nursery grounds in the floodplains of undisturbed river systems… the prolonged low Southern Oscillation… in combination with overexploitation of the fish stocks very probably led to the observed collapse of the sábalo fishery. (Smolders et al. 1999, 31)

It is evident that not only the well-being of fisheries, but also the residents of the Pilcomayo River Basin that depend on these fish resources, are significantly impacted by the natural flood patterns in the region. Displacement near the Pilcomayo River also occurs as a consequence of the lack of flood regulation and extreme weather, in addition to industrialization and fluctuations in agriculture.

The Pilcomayo River is prone to major flooding due to heavy and "continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers, streams, and coastal areas" (OAS 1984). The continuous, unregulated flooding not only hinders development by delaying agricultural processes, causing businesses to relocate and immobilize productivity, but also instigates an endless cycle of displacement and relocation of families that reside in the

Pilcomayo River Basin. The Pilcomayo River has a "highly dynamic nature of the floodplain and areas of sediment deposit…[where] there is a need for continuous monitoring of the floodplain as well as monitoring during the period of flooding for assessing the flood hazard…in terms of the risks they pose to existing and proposed development activities" (OAS 1984). Flood analysis has determined the economic potential of the Pilcomayo River Basin, and as water remains unregulated there cannot be a "sustainable improvement of human welfare" due to the constant need for relocation, especially during the wet season (WCD 2000, 2).

Pilcomayo: Downstream vs. Upstream

In Argentina and other developing countries, "floodplain dwellers … depend on production systems such as recession agriculture and floodplain grazing … Cessation of floods through dam construction is therefore likely to have serious negative effects on downstream livelihoods" (Acreman 2000, 21). While downstream residents benefit from natural floods, other communities that rely on the river have to adjust to floods differently. Because the Pilcomayo River has yet to be dammed, riverside residents have strived to adjust to natural flood patterns, and, in many cases, know that relocation may be necessary to avoid floods. Without water regulation, Pilcomayo dependents suffer from loss of access to resources due to drought during the dry season. Inversely, there is an extreme level of flooding in the Upper Pilcomayo that has impacted agricultural sustainability as well.

Natural cycles throughout the year impact the viability of agriculture and can actually help biological productivity such that "the decomposition processes of terrestrial and aquatic vegetation during flooding and flood recession [impact] the levels of organic detritus, for instance, [they] tend to be high in floodplains (Cordiviola de Yuan, 1992; Bayley, 1995)" (Smolders et al. 2002, 423). Despite the natural benefits of the Pilcomayo, there are consequences that stem from lack of resource management. The Pilcomayo debate brings the

Yacyretá case to light, where communities impacted by the construction of a dam have to adjust to a new kind of flooding.

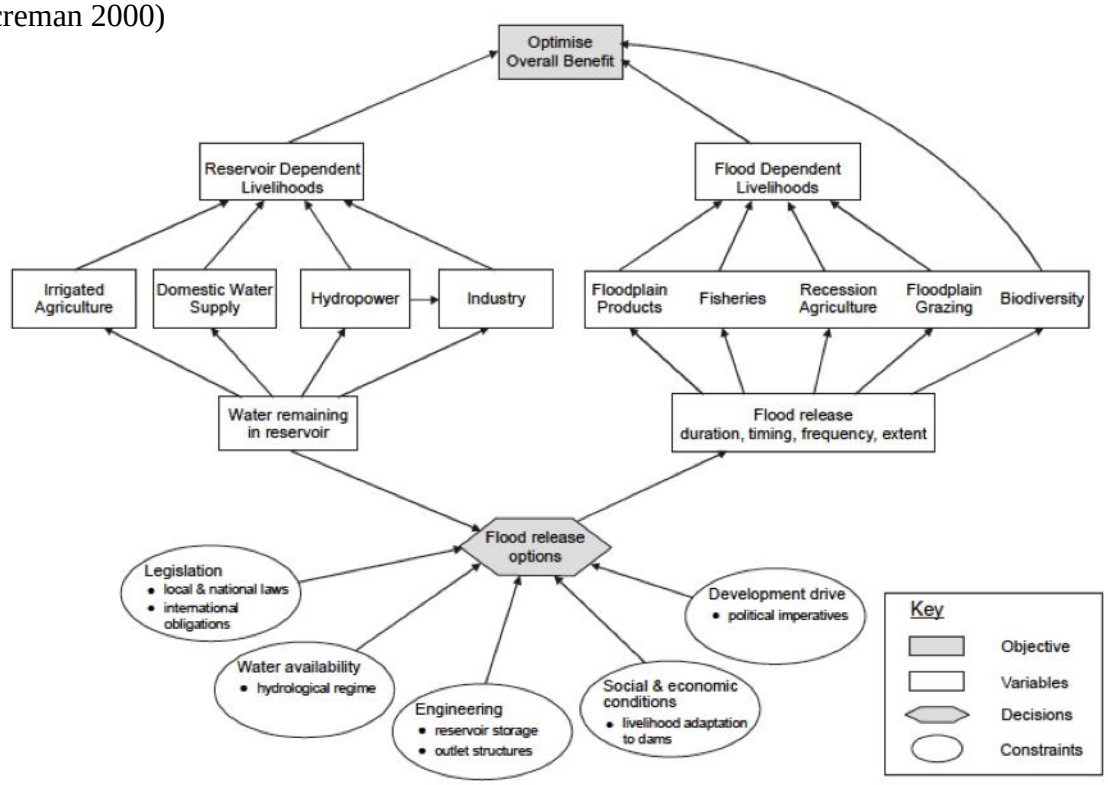
Yacyretá: Dam-related Flooding

Officials and promoters of the Yacyretá Dam emphasized that the dam would significantly benefit nearby residents despite the need for relocation. Because of necessary man-made floods:

> The Comisión Mixta Técnica… estimated that about 10 percent of the population of each city would be relocated… [and] the cities would benefit from the relocation... 'those zones, lacking sanitary installations and which are now subject to recurrent floods, will be replaced by modern units provided with these services. During the floods, the inhabited areas facilitate the propagation of contagious diseases, constituting a threat to public health and therefore should be eliminated. (Ferradás 1998, 73)

Overall the designed relocation units for affected communities appeared to be ideal because it would provide better living conditions compared to that of the flooded facilities and households. The communities that were well informed about relocation programs and flood protection were able to benefit from the modernized living schemes while others were not. In many cases, people are forced to relocate due to intentional and accidental flooding. As seen in Figure 4.2, when dam officials assess flood release options, they must evaluate the duration, timing, frequency, and extent of the flood because it affects factors such as floodplain products, fisheries, recession agriculture, floodplain grazing, and biodiversity (Acreman 2000). Similar to a flood dependent society, like the Pilcomayo River Basin, these factors determine the economic stability of the region. A reservoir-dependent community, such as the Posadaños upstream from the Yacyretá Dam, relies on the water remaining in the reservoir for irrigation, hydropower, and domestic water supply (Acreman 2000). As officials analyze when and how much water should be released from the dam and the necessary level of water increases in the reservoir, social and economic conditions, development drive, and water availability, must be considered.

Figure 4.2: *Trade-off between using water for managed flood releases and for other purposes* (Acreman 2000)



Those directly impacted by the Yacyretá Dam, specifically reservoir dependent livelihoods, have experienced changes in irrigated agriculture, domestic water supply, hydropower, and industry. As seen in Figure 4.2, these factors are significantly influenced by development drive. For example, if there is a rise in electricity demanded in greater Buenos Aires and it is imperative to increase generation at the dam, floods are produced more frequently and for a longer period of time in order to meet the demand. Environmental harms caused by controlled floods are often induced by this demand, and in Northern Argentina, the result has been grim: "the entire ecosystem is under threat from infrastructure which is … changing flooding patterns in order to produce short-term benefits in potential new soy and cattle production areas" (Alcorn et al. 2007, 2). Drastic changes in flood release can alter downstream fisheries, floodplain stability, biodiversity, and agriculture. It is crucial to identify the distinction

between downstream and upstream flooding when evaluating both expected and unexpected impacts on communities.

Regulated water directed upstream often hinders economic and environmental sustainability: "Diversion of upstream water supplies for irrigation, water supply, flood control, and hydroelectricity generation will interrupt the continuous downstream transfer of water and sediment which would otherwise take place. The result is a change in channel flow regime and morphology, sediment transport rates, water quality and water temperatures" (Barbier 2002, 4). This change in channel flow can affect the livelihood of migratory fish species that cannot flourish after significant changes in water temperature—and, in turn, impact the well-being of dependent communities. Floodplain ecosystems impacted downstream must pay for these costs. Intentional flooding caused by the dam has a major impact on the sustainability of human welfare of these communities. Consequences would not be as severe if individuals were properly informed about the negative changes in food resources, agricultural stability, and economic insecurity following the construction of the dam and its reservoir.

Dam-related Upstream Flooding

Intentional upstream flooding, a consequence of Yacyretá, is a result of "changes in the groundwater system and … [a] new groundwater connection generated since the construction of the Yacyretá … [and] the event of water level rise coincided with the closing of the main branch of the Paraná River during the dam construction" (Cózar et al. 2004, 238). Regulated upstream flooding can cause minor changes in agriculture and biological productivity if maintained at a certain level, and it can often help promote sustainability. Also, some controlled floods may occur in the hope of reducing the extensive damage from unregulated floods that would have occurred otherwise. Increases and decreases in the reservoir water levels harm the health of the riparian vegetation upstream because water temperatures are inconsistent.

It is inevitable that "when a dam is closed, the waters of its reservoirs begin to rise, submerging vast areas of land;" therefore, dam officials and those affected must be fully informed about potential consequences and whether or not relocation is necessary (Goldsmith 1984, 51). Additional increases in reservoir levels, on top of original quotas—often initiated to increase power generation to meet economic needs—can threaten the existence of wetlands and decrease biodiversity. With upstream flooding, one result of a reservoir, often comes displacement, agricultural harm, and biodiversity loss. Prior to the completion of the Yacyretá Dam, it was stated that "once the gigantic reservoir is filled, about 81,500 hectares in Paraguay and 25,000 in Argentina will be covered by water" (Ferradás 1998, 60). In addition to the loss of biodiversity and land productivity of the flooded area, economic hardships developed because agricultural lands lost value. Along with land degradation, the decrease in water quality of the reservoir had a significant impact on fish diversity and production. The environmental characteristics upstream from a dam (Table 4) are disturbed by the construction of the dam and reservoir where water levels change periodically. Table 4 indicates that there are more environmental losses upstream from a dam than there are gains.

Table 4: *Upstream Impacts*	(Acreman 2000)
Environmental Characteristic	**Economic effect, cost or benefit identified (C/B)**
Soil erosion and reservoir sedimentation	Reduced storage capacity, decrease in power, lower water quality (C)
Chemical changes in reservoir water quality	Loss of fishery production, change in treatment costs (C)
Loss of productivity of flooded area	Loss for timber/non-timber products, grazing (C)
Changes in flow rates out of dam	Changes in energy/water output from dam – change in use value (C)
Modification of aesthetic quality of river valley	Area becomes more or less attractive to humans (C/B)

The impacts described in Table 4 demonstrate that the upstream environmental costs associated with dam construction are significant enough to reevaluate whether the dam is worth the

economic growth and electricity generation downstream for agricultural and fishery-dependent communities.

Dam-related Downstream Intentional & Accidental Flooding

While the initial construction of a dam and its reservoirs increases water level, one of the goals is to regulate flooding. However, when it comes to downstream flooding, "many dams stop only small and average sized floods. When large floods do occur, the impacts can be significantly worse than prior to the dam, since the floodplain is likely to have been settled by people who considered they were safe from flooding" (Acreman 2000, ii). While officials and contractors of the dam may be aware of the consequences, it is unlikely that downstream communities are consistently fully informed. Upstream from Yacyretá in Posadas, for example, increased flooding impacted the quality of the land and its property value. Relocation programs indicated that flooded homes would be replaced by modern units and residents would have to be evicted in the process. The potentially relocated residents "worried about the possibility of a rise in the price of land and that this would particularly impinge upon the poorer residents of the city;" therefore, a law was passed that … "did not allow the sale or improvement on property that was supposedly affected by the dam" (Ferradás 1998, 74). As a result, residents remained in their flooded homes and suffered from additional long-term economic and health related problems.

Downstream communities are also impacted by diversion of water upstream for projects because it "reduces the flow of water through the watershed and drainage basin, directly affecting the supply of water available downstream for the floodplain" (Barbier 2002, 5). Lack of stable water resources downstream hurts the well-being of the ecosystems, as well as adjacent communities such as those in Ituzaingó, just south of the dam. If water is not being diverted upstream, there is also the likelihood of intentional downstream flooding when electricity demands are high.

This intentional downstream flooding also affects environmental sustainability and economic well-being due to alterations in river flow and sedimentation. Planned downstream flooding is often "timed to coincide with natural floods…which would carry a wider array of sediment sizes to eddies" (Collier et. al 2000, 78). Besides when a natural flood needs to be pushed along, there are many occasions when "water is released downstream not according to natural cycles but as directed by a region's hour-by-hour needs for electricity…we might see changes such as sand building up in one channel, vegetation crowding into another, and extensive bank erosion" (Collier et. al 2000, III). The ever-increasing demand for electricity, energy, and overall economic growth has merely caused greater frequency of floods. While downstream communities receive benefits "in terms of increased access to hydropower, irrigation and potable water, [there is] no consideration given to potential negative impacts" (Acreman 2000, 21). Downstream flooding affects the natural flow of rivers and fish migration patterns, which has negative implications for the communities that depend on the river for food, navigation, and recreation.

Accidental flooding is typically caused by "sudden, unplanned releases sometimes made from reservoirs to prevent dam failures without warning downstream communities" (Acreman 2000, i). Dam-related unplanned flooding can have significant negative effects on a community, such as forced removal from homes, loss of crops and food sources, and an increase in susceptibility to waterborne diseases. But natural unplanned flooding can also impact those that rely on a river that is not dammed. In conclusion, intentional flooding helps economic well-being and accidental flooding harms economic stability.

Some of the downstream impacts of dams "can affect both the quality and quantity of a water resource … impacts come from changes in ecosystem hydrology, release of sediment, land

clearing, changes to aquatic species migration patterns, seepage, dam failure, translocation of aquatic organisms (particularly in aquaculture) and changes in water quality parameters including nutrients, turbidity, salinity and pathogen levels" (Government of Western Australia WQPN 2006, 3). The Iberá wetlands just south of the Yacyretá Dam have suffered from rising water levels and flooding that has damaged biodiversity and decreased options for agriculture. Researchers have noted that projections made by the Argentina and Paraguay governments to increase the water levels of the reservoir at Yacyretá would cause major damages to the Iberá Wetlands by destroying biodiversity and economic conditions for local farmers. Such water level rises may even threaten the existence of the wetlands as a whole (Cózar et al. 2004, 284).

Table 5: *Downstream Impacts*	(Acreman 2000)
Environmental Characteristic	**Economic effect, cost or benefit identified (C/B)**
Silt removal from downstream flows	Clearer irrigation channels downstream (C/B), and loss of fertilizer functions of silt (C).
Chemical changes downstream water quality	Loss of fishery production, change in treatment costs. (C).
Changes in water temperatures	Changes in crop yields such as rice, loss of fisheries etc. (C/B)
Reduction in natural floods	Reduction in recession agriculture, reduction in flood damage to infrastructure. Changes in use, option and intrinsic values. (C/B)
Loss of access to resources	Livelihood impacts, loss of natural capital (C).

Demonstrated in Table 5, downstream environmental impacts of dams have a significant effect on agricultural sustainability especially when it comes to loss of access to resources, like natural capital found in nutrient land. Although the dam may result in clearer irrigation channels downstream, the loss of silt changes the natural flow of the river out to sea. Ultimately, dam-related flooding and natural inundation greatly impact the well-being of natural ecosystems and agricultural capabilities for communities whether the river in question is dammed or not. Due to the variety of downstream and upstream impacts of dam construction, it is up to specific

regulatory agencies to determine if these major environmental and economic costs are worth the benefits.

Irrigation and Agriculture

As described in Table 5, the changes in water temperature not only impact the livelihood of migratory fish but also agricultural productivity. In a country like Argentina, that relies heavily on agriculture as a source of economic prosperity, this environmental harm could drastically change the sustainability of human welfare in the region. Figure 4.3 demonstrates that in Misiones, home to the Paraná River, the total area of EAP (farming and livestock holdings) devoted to forestry as of 2002, decreased after the Yacyretá Dam began operation. Although land used for forestry had decreased from before the dam was completed to after operation began, more suitable land for agriculture was used because of greater access to irrigation. While roads, parks, and housing remained relatively the same during this time period, due to industrialization during the beginning stages of construction (prior to 1988), more arable land became available to farmers and natural pastures were better utilized. On the other hand, in Formosa (Figure 4.4), along the Pilcomayo River, total area of natural pastures and forests increased during this same period indicating that biodiversity was maintained and the natural habitat remained intact. However, because the residents of Formosa did not benefit from the construction of a large dam, in terms of industrial development, the area of land devoted to roads, parks, and housing projects decreased. Figure 4.4, with the help of Tables 6 and 7, indicates that even though Formosa did not benefit from irrigation services provided by the Yacyretá Dam, farmers still had access to other irrigation systems that effectively improved agriculture.

Figure 4.3 Misiones: Total area of EAP with definite limits, area devoted to other uses. Years 1988 and 2002

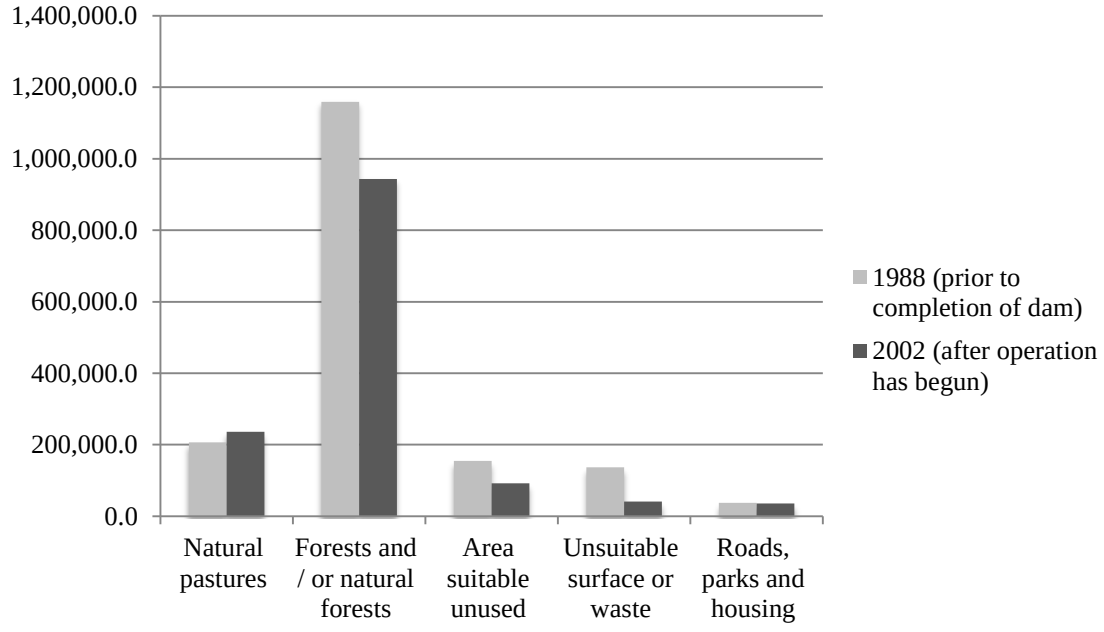
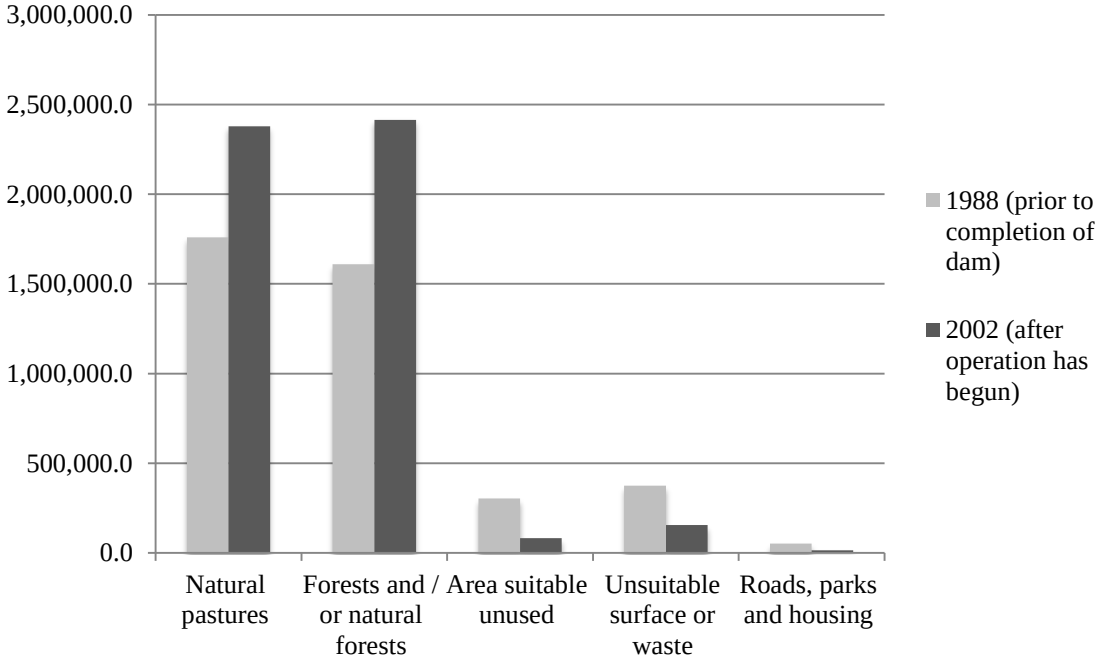


Figure 4.4 Formosa: Total area of EAP with definite limits, area devoted to other uses. Years 1988 and 2002



Source: Instituto Nacional De Estadística y Censos

Table 6: *Number of EAP watered and irrigated by surface water source, by province. Year 1988*

Province	**Number of EAP and surface area**	**Irrigated Area**			
		Total	*Source of Water*		
			Above Ground	*Underground*	*Above and underground*
Formosa (Pilcomayo)	EAP	210	159	45	6
	ha	6089	5211.5	773.1	104.4
Misiones (Paraná)	EAP	323	218	87	18
	ha	1358.4	1208.3	132	18.1

Table 7: *Number of EAPs that water, and area actually irrigated by system, by province. 2002*

Province	**Number of EAP and surface area**	**Irrigation System**					
		Total	*Gravitacional (gravitational)*	*Por aspersion (spray)*	*Localizado*		
					Goteo (drip)	*Microaspersion (microsprinklers)*	*Otros*
Formosa (Pilcomayo)	EAP	122	39	20	8	2	46
	ha	4001.5	2169.8	1244	508.2	20	51.3
Misiones (Paraná)	EAP	88	12	39	33	5	16
	ha	170	20.3	79.6	29.8	4.4	35.9

Source: Instituto Nacional De Estadística y Censos

In 2002, after operation of the Yacyretá Dam began in Misiones, the total area of land that used an irrigation system was only 27 percent of the total area irrigated by a surface water source in 1988, during the construction of the dam. Total EAP in Formosa that used an irrigation system, as of 2002, was 58 percent of the total EAP irrigated by a surface water source during 1988. This data indicates that once operation began, there was less of a need for farmers to use the indicated irrigation systems. In turn, farmers in Misiones utilized irrigation services provided by the Yacyretá Dam project. Formosa, on the other hand, had to rely more on alternate irrigation systems because the Pilcomayo had yet to be managed by large water resource development projects such as those along the Paraná River.

Sedimentation and Silt Removal

In addition to the availability of irrigation systems that affect agriculture, sedimentation also plays a major role in determining environmental well-being for a community. Sedimentation and erosion remain two of the key environmental issues that impact all rivers, despite the number of large and small water resource development projects. There are benefits of maintaining natural floodplains when it comes to sedimentation control because "when portions of floodplains are preserved in (or restored to) their natural state, they… reduc[e] the number and severity of floods, [help] handle stormwater runoff and minimiz[e] non-point water pollution." Also, floodplains "[allow] floodwater to slow down, sediments settle out, thus maintaining water quality. The natural vegetation filters out impurities and uses excess nutrients" (Woodriver.org 2012). Some of the significant benefits of natural floodplains are their ability to reduce sedimentation and provide rich biodiversity.

When it comes to anthropogenic sedimentation and erosion changes, dams can decrease "the amount of sediment being transported downstream. Dams may trap sediment flows from upstream preventing them from normal downstream settlement, resulting in scouring and erosion of the waterway. This may cause plants to be uprooted resulting in significant damage to riparian vegetation" (Government of Western Australia WQPN 2006, 15). Sedimentation can play an important role in a river's natural ecosystem; however, regulation can also benefit the river's productivity. The benefits to dam construction when it comes to sedimentation include "improved water quality downstream of the dam that makes water treatment easier and less costly … enhanced recreation, improved local living conditions and facilitating riparian and aquatic wildlife" (ICOLD 1999, 9). On the other hand, the costs of reservoir sedimentation "are progressive loss of storage capacity, and increased erosion in downstream river channels" (ICOLD 1999, 9). While sedimentation upstream may result in potentially cleaner water

downstream, natural ecosystems and riparian vegetation are so greatly impacted that allowing a river to run its natural course may provide more benefits than those of a river that is dammed. On the other hand, the Paraná River has also experienced some benefits of sedimentation influenced by the construction and operation of a large dam.

Water regulation schemes provided by dams have demonstrated a means of altering erosion and sedimentation levels. Specifically along the Paraná River, "upstream reservoirs of all sizes act as de facto sedimentation traps, and downstream sites will experience reduced sediment loading… 39 major structures along the Paraná River and its tributaries in Brazil, above the Yacyretá dam below Posadas, Argentina… are responsible for dramatically decreased sediment yields at the Yacyretá dam site" (Morris and Fan 12.2.4, 1998). This is a significant example where the construction of a dam has positively affected sedimentation and erosion levels of nearby ecosystems. However, it is important to acknowledge that the initial construction of the dam determines the effectiveness of the sedimentation control. For example "poor compaction of the dam structure can lead to increased seepage and aid the transport of contaminants. This can also increase the erosion from the dam, resulting in sediment being transferred downstream" (Government of Western Australia WQPN 2006, 14). If a dam is constructed properly, "impoundment [still] prevents a rivers' silt from being carried to the sea…when the waters downstream of a dam are deprived of their silt content, this causes the erosion of land in the delta" (Goldsmith 1984, 61). The increase in silt and the high salt content no longer "provide[s] suitable habitats for riverine fish" (Goldsmith 1984, 94). Along with influencing the well-being of the human population, fish are also impacted by sedimentation, water resource development projects and lack thereof.

Overall, the natural benefits of floodplains associated with sedimentation control demonstrate that by allowing floods to slow down and minerals to break apart, cleaner water can result from maintained floodplains. While there are significant benefits of dam construction in terms of improving downstream water quality, the negative consequences of increased sedimentation upstream outweighs these gains. If natural floodplains are managed properly and utilized to provide the utmost benefits for communities, such as providing rich biodiversity and the potential for agricultural development, a river left to run its natural course can experience substantial gains.

Fisheries

Along the Pilcomayo and the Paraná River, communities are affected by the changes in fish migration patterns due to natural, accidental, and intentional flooding. "Production in a particular year depends on the amount of water that remains in the floodplain after a flood… Hence, fish catches in floodplain rivers are frequently related to the extent of the floods in the preceding years (Krykhtin, 1975; Welcomme, 1979; Laë, 1992)" (Smolders et al. 2002, 423). Controlled flooding has the potential to better regulate the productivity of a river, especially when it comes to the livelihood of migratory fish populations, as well as provide benefits to the inhabitants of the Pilcomayo River Basin. Regulated flooding along the Pilcomayo River would have the potential to help fish migration because droughts would be less severe allowing the river to run consistently from the Upper Pilcomayo to the Lower Pilcomayo Basin. Nonetheless, there are consequences of obstructing a natural river.

Dam infrastructure has definitely made its mark on the environmental well-being of the region in addition to natural weather patterns that impact the viability of water resources. The economic stability and environmental sustainability along both the Pilcomayo River and the Paraná River depend greatly on fishing, and water resource development projects can harm the

livelihood of fish populations as well. One of the most important economic trade-offs to consider is the gain in hydropower for loss of fishery stability. "Society is assumed to value both its consumption of a numéraire good, produced via hydropower, and its consumption of [fish]. In addition, the society attributes a value to the stock of [fish] … [where] more electricity generation means less [fish] and vice versa" (Johansson 2011, 244). If a community relies more on fisheries than agriculture and industry, the need for hydropower would be questioned. Nonetheless, if a community does not have stable agricultural resources, and cannot rely on fisheries, hydropower may be a priority over fish. A decrease in profit generated from fisheries impacts the local economy as well as the domestic fish market. Specifically along the Paraná, fish passage systems in "lower basin dams [such as] Yacyretá… fail[s] to transfer sufficient numbers of upstream migrants to sustain populations of migratory species. Fish passage efficiency of target species in the fish elevators at Yacyretá is less than 2%" (Oldani et al. 2007, 89). Along with inefficient fish passage systems, the changes in water temperature and water quality greatly impact fishery productivity.

In addition to changes in fish resources, populations affected by flooding, as a result of a dam, suffer from a reduction in human welfare due to a decrease in other food sources. Specifically, "the protein value of fish caught in the river before a dam is built; of the crops in the farmland that is flooded; and of the wild game that inhabits the often extensive croplands, rangelands, and forests that are drowned by a reservoir…cause a net loss in available protein" (Goldsmith 1984, 100). A loss in food sources can put significant stress on rural communities in developing countries where food is not as readily available and imports are scarce.

Overall, the social and economic losses due to the negative impacts of the Yacyretá Dam on fishery sustainability challenge a community's hope for a "sustainable improvement of human

welfare" because no longer can consumers be guaranteed that fish will be available and that they will be healthy enough to sell or consume (WCD 2000, 2). The Pilcomayo River produces "large areas of land [that] are inundated by the river during the rainy season … [and] floodplains serve as important feeding-grounds for many migratory fish species" enabling residents of the Pilcomayo River Basin to benefit from these productive fisheries (Smolders et al. 2004, 1746). The costs inflicted on the livelihood of migratory fish species are significant enough to consider ecosystem well-being when determining whether a dam could be a solution for achieving a sustainable development in a particular community. Ultimately, the harm to fisheries along the Paraná, due to the construction of the Yacyretá Dam, demonstrates a significant environmental and economic impact on human welfare in the region.

A Dam for Pilcomayo? Will it Help *Environmentally*?

The Paraná River and the Pilcomayo River are similar agriculturally because in both regions "agricultural activities rely heavily on generally abundant rainfall. However, occasional droughts do occur and crops fail" (Ferradás 1998, 68). While economists and capitalists—often promoters of modernization theory—encourage the implementation of large dam projects to stimulate economic growth, activists and scholars in the agricultural and environmental sector believe otherwise. According to the Organization of American States, "the Pilcomayo is one of the most complex sub-basins of the Plata River system. It covers 272,000 km^2 (107,000 sq. mi.), about 8.4 percent of the Plata River basin," (OAS 1984) and due to its complexity, agricultural development schemes and irrigation projects may be the solution to achieving environmental sustainability.

A large dam system can be beneficial for sediment regulation especially in regions such as the Pilcomayo where navigation is disrupted because "alluvial sedimentation has interrupted the former direct connection between the upper reaches of the Pilcomayo River and the Paraguay

River" (Los Amigos del Pilcomayo 2009). Communities along the Pilcomayo would be economically harmed by environmental displacement as a result of dam construction because "losses from these rich alluvial fields cannot easily be compensated by the new, less-fertile lands proposed for settlement" (Edmonds 2000, 165). Ultimately, sedimentation can both benefit and harm the well-being of communities dependent on such rivers, but considering the extreme effects of high sedimentation in the Pilcomayo on the community's livelihood, regulation may be the solution to prolonging its productivity.

However, there have in fact been a variety of strategies for economic development that are negatively perceived by communities along the Pilcomayo River. For example, "plans for the development of small dams to fuel speculative land sales for soy farming investments … will displace criollo and Indigenous communities, forcing them to abandon the river along which they lived for centuries" (Alcorn 2012, 166). Although small dams may reduce upstream and downstream flooding, the construction of the reservoirs and resulting soy farms could displace a comparable number of residents as a natural flood would. Displacement caused by industrialization and agricultural growth is a common problem faced by numerous communities near the Yacyretá Dam as well.

Due to exploitation of the Pilcomayo's fish resources and irregular weather patterns of ENSO, the natural riverine ecosystems are hurt by lack of government intervention and regulation. While both natural and anthropogenic issues hinder economic growth along the Pilcomayo, water management in the region has the potential to better regulate unplanned floods, reduce drought frequency, and help decrease exploitation of fish resources. For example, due to dam construction along the Paraná, "the two major fluvial components of the Río de la Plata drainage net, namely the Paraná and Uruguay rivers, exhibit a strong interannual oscillation … in

phase with El Niño events. Both rivers show noteworthy streamflow increases during ENSO warm events (or El Niño) and normal to low discharges during cold events (or La Niña)" (Pasquini 2006, 392). Ultimately, dam construction has the potential to reduce flooding and the damage caused by natural phenomena, such as El Niño.

Dam proponents claim that in order for the Pilcomayo River Basin to flourish, a dam is necessary. It is believed that arable land throughout the Pilcomayo basin has exceptional potential for agricultural growth if irrigation is made available. A proposed solution is the "construction of regulating waterworks in the Upper Pilcomayo in Bolivian territory where the necessary topographical and geological conditions exist to build reservoirs with adequate storage so as to regulate river discharge" (Biswas et al. 1999, 162). Flood control in the Upper Pilcomayo may be ideal for agricultural stability; however, the Yacyretá Dam has demonstrated that there are negative consequences that come with dam construction, especially when victims are not properly informed.

Environmental Factor	**Formosa (Pilcomayo River)**		**Misiones (Paraná River)**	
	Upstream	*Downstream*	*Upstream*	*Downstream*
Construction-induced harms	N/A	N/A	C	C
Flooding & Agriculture	C	C	C	B
Sedimentation	C	C	C	B
Fisheries	C	B	C	B

Ultimately, the Pilcomayo River could experience environmental gains and losses if construction of a large dam were to occur. Such losses include construction-induced harms that occur as soon as water is deterred for construction, negative upstream impacts on agriculture due to increases in reservoir water levels, costs associated with high levels of sedimentation build up in the reservoir, and dangers to fisheries that can no longer migrate and risk endangerment as a result of changes in water temperature. Benefits to people are primarily seen downstream and

include improved agriculture, reduced sedimentation, and better water quality for fisheries. It is up to the potential beneficiaries and victims to determine whether the economic gains associated with increased access to electricity and job growth are worth the temporary environmental changes.

Conclusion

As international water supplies become more and more scarce due to population growth and industrialization, large water resource development projects are often proposed with the ultimate goal of regulating water while increasing economic activity. Dams are constructed in hopes of stimulating economic growth, generating hydropower, providing irrigation services, and benefiting agricultural sustainability. This investigation has identified the similarities between the Pilcomayo River and the Paraná River, and demonstrated that although they were once on the same path, the construction of the Yacyretá Dam has brought enhanced economic welfare to communities that rely on the Paraná River. Natural flooding of the Pilcomayo River, due to irregular weather patterns and lack of water resource management, has hindered economic growth in the region. When water is not regulated, agriculture cannot be consistently productive neither can ecosystems be maintained. The debate addressed is whether the benefits of a dam to people—irrigation, hydropower, and economic growth—outweigh the costs of flooding and the increase in displaced communities. Without a dam, the residents of the Pilcomayo River Basin do not have to worry about accidental floods from dams or the fear of having to relocate due to construction and intentional water level rises; however, these communities still must be prepared for severe weather induced floods, drought, irregular agriculture, and unstable access to fish resources.

In summary, the construction of the Yacyretá Dam increased employment rates in the Misiones province of Argentina while the lack of development and minimal water management along the Pilcomayo River, in Formosa, has only resulted in slight changes of unemployment levels. Due to the length of the construction period, the creation of new jobs for workers from Misiones as well as residents of Paraguay contributed to significant long-term economic growth in the region. The need for skilled labor, particularly the need for engineers and contractors, reduced the occurrence of brain-drain and more highly educated Argentines and Paraguayans remained in the country when this large dam project began, also contributing to the region's economic well-being. Power generated from the Yacyretá Dam has increased energy access for the residents of Misiones, therefore resulting in sustainable development.

Heavy rainfall in Misiones and Formosa has caused frequent natural floods that impact agricultural sustainability. Migratory fish are greatly impacted by flooding—whether it is natural or anthropogenic—and lack of stable fish resources can inhibit sustainable growth in human welfare. In Formosa, natural floods do in fact facilitate rich biodiversity in the floodplains, nutrient soil, and provide a breeding ground for migratory fish. Unfortunately, lack of water regulation has enabled high levels of sedimentation to damage the flow of the river. Although the Yacyretá Dam along the Paraná River has provided general flood control and water regulation, minor floods still occur. The reduced incidence of natural floods has benefited downstream communities and improved overall agricultural productivity. But, the new intentional and accidental floods along the Paraná River, a consequence of dam and reservoir construction, cause environmental, economic, and social harms to the local populations, which are often forced to relocate.

Natural flood-induced displacement is an issue along the Pilcomayo River and the Paraná River because extreme weather patterns, like El Niño, cannot be completely controlled. Dam-related downstream flooding can be both intentional and accidental. When water is released due to sudden increases in electricity demand, and downstream communities are not properly warned, individuals can become displaced and lose everything. Accidental spillovers also have the same effect. Intentional downstream flooding, in contrast, occurs to reduce the severity of natural floods and communities can be prepared because such floods are often seasonal.

Dam-related upstream flooding occurs when there is a boost in energy demand and, in anticipation, reservoir water levels must increase. Flooding that occurs upstream from a dam harms ecosystems, agricultural productivity, and fishery well-being due to changes in water temperature and irregular increases and decreases in water levels. Ecosystems upstream from a dam are also affected by heavy loads of sedimentation buildup in the reservoir. In the meantime, dams reduce sedimentation downstream and improve water quality for irrigation and human consumption. The enhanced water quality downstream outweighs the upstream costs, and this demonstrates that a dam has the potential to provide agricultural sustainability when it comes to sedimentation control. All communities can benefit from improved water quality, especially when it supports the livelihood of fisheries.

Upstream fisheries along the Pilcomayo River are negatively impacted by the lack of water regulation because during the dry season, fish are unable to migrate downstream. Concurrently, fisheries downstream of the Pilcomayo River greatly benefit from nutrient-rich floodplains. In the case of a dam, fisheries upstream are harmed by changes in water temperature and downstream fisheries benefit from better water quality. Gains to downstream fisheries also

contribute to the economic well-being of the community that depends on these resources for survival.

Improved water quality in the Paraná River has fostered an increase in sustainable agriculture. Although land devoted to forestry decreased in Misiones, the use of arable land and natural pastures increased allowing better farmlands for grazing. In Formosa, natural forests and pastures increased during the construction period, but the development of roads, parks, and housing decreased, while improving in Misiones. Even though irrigation services provided by the Yacyretá Dam project facilitate agricultural growth in Misiones, there are still other available irrigation systems that enable agricultural productivity in Formosa. While the Upper Pilcomayo is unsuitable for agriculture, additional human welfare improvements would be seen in Formosa if water regulation is implemented because the Lower Pilcomayo River is suitable for annual crop rotations, improved pasture, grazing, and forestry.

Lastly, displacement is a significant issue for both natural flowing and dammed rivers. Displacement caused by dam construction results in a forced lifestyle change for the communities affected. Fortunately, in the Yacyretá case, relocation programs were implemented and many families received compensation, educational opportunities, and job training. In addition to economic benefits there were social hardships associated with these relocation programs; housing developments often lacked necessary sanitation services resulting in health problems among the relocatees. With the analysis of data regarding households with unsatisfied basic needs (access to housing, water, and sewage), it is inferred that throughout the construction period, residents of both Formosa and Misiones experienced an overall decrease in unsatisfied basic needs and a relatively similar amount of available sanitary services. Therefore, even without the relocation programs, the communities along the Pilcomayo River and the Paraná

River would have had similar access to basic needs and would have benefited from an overall improvement in human welfare. While there may have been economic and social hardship, the long-term benefits, such as access to electricity and overall economic growth for the region, demonstrate that there was in fact hope for a "sustainable improvement of human welfare" (WCD 2000, 2).

Study Limitations & Suggestions for Future Studies

This research raises additional questions regarding subsequent factors that also impact the economic and environmental well-being of a community affected by a large dam. I emphasize the importance of investigating these unanswered questions in future studies. This thesis' primary goal was to compare two similar rivers, one that was dammed and one that was not, and determine whether the dam had facilitated a "sustainable improvement of human welfare" (WCD 2000, 2). I assessed economic impacts, such as employment levels and access to electricity, as well as influences on the environment, such as changes to agriculture, sedimentation, and fisheries. These findings do not address whether the improved economic well-being of the Misiones residents along the Paraná River during the time of Yacyretá construction might have been due to other social institutions beyond the dam construction, such as international environmental agreements, economic development programs, or the creation of new jobs unrelated to the dam. This study has also has examined "average" effects, without investigating differential impacts across social groups, for example, whether the dam primarily benefited men rather than women, or Paraguayans at the expense of indigenous people, or migrants rather than local laborers. The construction and operation stages of the Yacyretá Dam could have also had different impacts on minorities or those from lower income communities. For example, highly educated communities may have been more aware of the environmental and economic consequences and, in turn, would have been better prepared to find new work or relocate sooner.

I designed this case study so that this framework could be applied to other rivers also affected by a large dam. This overall structure could be used during the decision-making process before the construction of a dam to evaluate how it will potentially impact the economic and environmental well-being of the surrounding community. The opportunity to explore the Pilcomayo River Basin from a more hands-on perspective, and get to know the local residents that depend on the river, would provide the researcher with more detailed answers regarding the economic stability of this region. With this, one would be able to assess, based on the level of "happiness" of these two riverside communities, who appears to live a more economically and environmentally sustained lifestyle. Further research could also determine whether there was ways the Yacyretá Dam could have had fewer harms had victims been better informed.

Environmental harm and economic growth go hand in hand, especially when it comes to the effects of dams on communities. In this study, the Pilcomayo case demonstrated that life without a dam includes numerous natural environmental and economic consequences. But of course, there are benefits of allowing a river to run its natural course as well. The analysis of the Yacyretá Dam indicated that although there were long term and short term environmental harms associated with the construction and operation stages of the dam, the economic gains provided a greater "sustainable improvement of human welfare" compared to that of the residents along the Pilcomayo River (WCD 2000, 2).

Bibliography

Acreman, Mike. "Managed Flood Releases from Reservoirs: Issues and Guidance." *Thematic Review II.1: Dams, ecosystem functions and environmental restoration* (2000). Print.

Alcorn, Janis B., Alejo Zarzycki, and Luis Maria De La Cruz. *Governance and Ecosystems Management for the CONservation of BIOdiversity*. *GEM-CON-BIO Case Study Report: Pilcomayo Trinational River Basin, Argentina. Project #028827*. Fundación Yangareko, July 2007. Web. 16 Aug. 2011.

Alethea E.M. and Kenitiro Suguio. "Quaternary colluvial episodes (Upper Paraná River Hydrographic Basin, Brazil): Fig. 1- Geographic location map of the La Plata Hydrographic Basin in South America (A), emphasizing the UPRHB (B)." Anais de Academia Brasileira Ciências [online]. 2010, vol.82, n.3. pp. 701-715. Mar. 2012, Web, Figure 2.1.

Araya, Patricia R., Angelo A. Agostinho, and Jose A. Bechara. "Population structure, growth and fishery yield of Leporinus acutidens (Valenciennes, 1837) (Teleostei: Anostomidae) in Yacyretá Reservoir (Argentina): Sampling area. 1-Yabebiry Stream; 2- Nemesio Parma; 3- Puerto Valle; 4- Puerto Jupiter." Neotropical Ichthyology. Porto Alegre, v. 6, n. 1, Mar. 2008. Mar. 2012, Web, Figure 2.3.

Archer, J., K.A. Hudson-Edwards, D.A. Preston, R.J. Howarth, and K. Linge. "Aqueous Exposure and Uptake of Arsenic by Riverside Communities Affected by Mining Contamination in the Rio Pilcomayo Basin, Bolivia." *Mineralogical Magazine* 69.5 (2005): 719-36. Web.

"Argentina - Misiones, Tierra De Colores Fuertes." *Argentina.ar*. Argentina En Noticias, 27 May 2008. Web.

Barbier, Edward B. "Upstream Dams and Downstream Water Allocation the Case of the Hadejia'Jama'are Floodplain, Northern Nigeria." Laramie, WY: Department of Economics and Finance, University of Wyoming, 2002.

Barrionuevo, Alexei. "Patagonia Dam Project Inspires Outrage in Chile." *The New York Times*. 17 June 2011. Web. 16 Oct. 2011.

Benefits and Concerns About Dams. International Commission on Large Dams (ICOLD): Committee on Public Awareness and Education, 1999.

Biswas, Asit K., Newton V. Cordeiro, Benedito P.F. Braga, and Cecilia Tortajada, eds. *Management of Latin American River Basins: Amazon, Plata, and São Francisco*. Tokyo: United Nations UP, 1999. Print.

Braun, Miguel. *The Political Economy of Debt in Argentina, or Why History Repeats Itself*: Centro de implementación de políticas publicas para la equidad y el crecimiento, 2006.

"Brazil and Paraguay in Power Deal." *BBC News - Home*. 25 July 2009. Web. 18 Oct. 2011.

Canziani, Graciela A., Rosana M. Ferrati, Claudio Rossi, and Diego Ruiz-Moreno. "The Influence of Climate and Dam Construction on the Ibera Wetlands, Argentina." *Reg Environmental Change* 6.4 (2006): 181-91. 20 May 2006. Web. 16 Oct. 2011.

"Coastal Zone Act Reauthorization Amendments (CZARA): Chapter 6.3:A Management Measure for Erosion and Sediment Control." *Section 6217*. Ed. Environmental Protection Agency: EPA and National Oceania and Atmospheric Administration, 1993. Print.

Collier, Michael, Robert H. Webb, and John C. Schmidt. *Dams and Rivers: A Primer on the Downstream Effects of Dams*. Tucson, AZ: U.S. Dept. of the Interior, U.S. Geological Survey, 1996. Print.

Cózar, A., R. Ferrati, C.M. García, J.A. Gálvez, and C. Rossi. "Human-threatened ecosystem: new signs of groundwater connection between Yacyretá reservoir and Iberá wetland (South America)." *Science of the Total Environment* 337 (2005) 281– 286. 6 July 2004. Web. 3 Nov 2011.

Dams and Development: A New Framework for Decision-Making: the Report of the World Commission on Dams: An Overview. London: Earthscan, 2000. *International Rivers*. World Commission on Dams, Nov. 2000. Web. 10 Oct. 2011.

"Dam Construction and Operation in Rural Areas." Government of Western Australia. Department of Water. Water Quality Protection Note 53. Australia 2006.

Economics Group. Technical Service Center. *Economic Analysis of Dam Decommissioning*. By Jonathan L. Platt. Denver, CO: U.S. Dept. of the Interior, Bureau of Reclamation, 2003.

Edmonds, Richard L. *China's Economic Growth: The Impact on Regions, Migration and the Environment*. Ed. Terry Cannon. Houndmills: Macmillan, 2000. Print.

Ehrhardt-Martinez, Karen, and Edward M. Crenshaw, J. Craig Jenkins. "Deforestation and the Environmental Kuznets Curve: A Cross-National Investigation of Intervening Mechanisms." *Social Science Quarterly* 83.1 (2002). Print.

Elhance, Arun P. *Hydropolitics in the Third World Conflict and Cooperation in International River Basins*. Washington, D.C.: United States Institute of Peace, 1999.

Ferradás, Carmen A. "From Vegetable Gardens to Flower Gardens: The Symbolic Construction of Social Mobility in a Development Project." *Human Organization* 56.4 (1997): 450-61. Print.

Ferradás, Carmen A. *Power in the Southern Cone Borderlands: An Anthropology of Development Practice*. Westport, CT: Bergin & Garvey, 1998. Print.

Frederick, Kenneth D. *Water Management & Agricultural Development: a Case Study of the Cuyo Region of Argentina*. Baltimore: Published for Resources for the Future by Johns Hopkins UP, 1975. Print.

Galvan, Dennis. "III. Theories & Practices of Induced Social Change." 2011 University of Oregon. Lillis Business Complex, Eugene. 24 October 2011.

Goldsmith, Edward, and Nicholas Hildyard. *The Social and Environmental Effects of Large Dams*. Camelford, Cornwall: Wadebridge Ecological Centre, 1984.

Goodman, Joshua. "Argentina's Provincial Profligates (Int'l Edition) Their Spending and Patronage Is Busting Buenos Aires' Budget." *Bloomberg Businessweek Online* 2001, sec. International- Latin American Business. Web.

Gordillo, Gastón R. "Canals for a Wild River: Borders and Aboriginal Utopias in the Argentinean Chaco." *CIBR Working Papers in Border Studies* CIBR/WP01-2 (1999). Print.

Hanratty, Dannin M. and Sandra W. Meditz, editors. "Itaipú, Yacyretá, and Corpus." *Paraguay: A Country Study*. Washington: GPO for the Library of Congress, 1988. Web.

Hasan, Z. *Appropriate Decision Making Procedures for New Dams, Particularly for Irrigation, Drainage, and Flood Management*. Ed. K.N. Sharma. New Delhi, India: International Commission on Irrigation and Drainage, 2004. Print.

Holmes, Gillian S. "Concrete Dam." *How Products Are Made: Volume 5*. Advameg, Inc., 2012.

INDEC: Instituto Nacional De Estadística Y Censos. INDEC. Web.

Janis Alcorn, Alejo Zarzycki, Alonzo Zarzycki,, and Luis Maria de la Cruz. "The Pilcomayo River Basin Argentina Presentation." (2007). Print.

Janis B. Alcorn, Alejo Zarzycki O., Luis Maria de la Cruz. "Gem-Con-Bio Case Study Report Pilcomayo Trinational River Basin, Argentina." 028827 (2007). Print.

Johansson, Per-Olov, and Bengt Kriström. "The New Economics of Evaluating Water Projects." *Annual Review of Resource Economics* 3.1 (2011): 231-54. Print.

Khagram, Sanjeev. *Dams and Development: Transnational Struggles for Water and Power*. Ithaca, N.Y: Cornell UP, 2004. Print.

Lee, Terence R. *Water Resources Management in Latin America and the Caribbean*. Vol. 16. Boulder: Westview, 1990. Studies in Water Policy and Management. Print.

"Los Amigos Del Pilcomayo - Rivier De Pilcomayo." *Los Amigos Del Pilcomayo - Homepage*.

15 June 2009. Web. 21 Nov. 2011.

"Marco De Referencia." *Dirección Ejecutiva - Comisión Trinacional Para El Desarrollo De La Cuenca Del Río Pilcomayo*. Pilcomayo.net. Web. 18 Oct. 2011.

McCully, Patrick. *Silenced Rivers: The Ecology and Politics of Large Dams*. London: Zed, 2001. Print.

"Mi Provinica." *Portal Oficial Del Gobierno De La Provincia De Formosa: El Portal De Nuestra Gente*. Gobierno De La Provincia De Formosa-República Argentina. Web.

Miguel, Carlos De, Jose Duran Lima, Paolo Giordano, Julio Guzman, Andres Schuschmy, and Masakazu Watanuki, eds. *Modeling Public Policies in Latin America and the Caribbean*. Santiago, Chile: United Nations, ECLAC, 2010.

Miller, J.R., K.A Hudson-Edwards, P.J Lechler, D Preston, and M.G Macklin. "Heavy Metal Contamination of Water, Soil and Produce within Riverine Communities of the Rio Pilcomayo Basin, Bolivia." *Science of The Total Environment* 320.2-3 (2004): 189-209. Print.

Mitchell, Ronald B. *International Politics and the Environment*. London: SAGE Publications, 2010. Print.

Monahan, Jane. "Soybean Fever Transforms Paraguay." *BBC News - Home*. 6 June 2005. Web. 18 Oct. 2011.

Montero, Hector E., and Miguel S. Dorfman, eds. *Statistical Yearbook of the Argentine Republic 1999*. Vol. 15. Buenos Aires: Instituto Nacional De Estadística Y Censos, 1999. Print.

Morris, Arthur S. "The Development of the Irrigation Economy of Mendoza, Argentina." *Annals of the Association of American Geographers* 59.1 (1969): 97-115.

Morris, Gregory L., and Jiahua Fan. *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs, and Watersheds for Sustainable Use*. New York: McGraw-Hill Companies, 1998. Web.

Nardi, María Andrea. *Rural Development and Territorial Dynamics in the Province of Misiones, Argentina*. Lund: Lund University, 2011.

"Natural and Beneficial Functions of Floodplain." *Wood River: Flood Protection*. City of Wood River, 2 Mar. 2012.

Oldani, Norberto Oscar, Claudio Rafael Mariano Baigún, John Michael Nestler, and Richard Andrew Goodwin. "Is Fish Passage Technology Saving Fish Resources in the Lower La Plata River Basin?" *Neotropical Ichthyology* 5.2 (2007): 89-102.

Organization of American States. Department of Regional Development Secretariat for Economic and Social Affairs. *Integrated Regional Development Planning: Guidelines and Case Studies from OAS Experience*. Washington, D.C.: National Park Service and U.S. Agency for International Development, 1984. Case Study 3- The Pilcomayo River Basin Study: Argentina, Bolivia, Paraguay.

Organization of American States. Department of Regional Development Secretariat for Economic and Social Affairs. *Integrated Regional Development Planning: Guidelines and Case Studies from OAS Experience*. Washington, D.C.: National Park Service and U.S. Agency for International Development, 1984. Case Study 3- The Pilcomayo River Basin Study: Argentina, Bolivia, Paraguay: *Pilcomayo River Basin and Potential Land Use*. Figure 4.1.

Organization of American States. Department of Regional Development Secretariat for Economic and Social Affairs. *Integrated Regional Development Planning: Guidelines and Case Studies from OAS Experience*. Washington, D.C.: National Park Service and U.S. Agency for International Development, 1984. Case Study 3- The Pilcomayo River Basin Study: Argentina, Bolivia, Paraguay: *Location of the Pilcomayo River Basin, Argentina, Bolivia, and Paraguay*. Figure 2.2.

Pasquini, Andrea I., and Pedro J. Depetris. "Discharge Trends and Flow Dynamics of South American Rivers Draining the Southern Atlantic Seaboard: An Overview." *Journal of Hydrology* 333 (2007): 385-399.

Paoloni, J.D., M.E. Sequeira, C.E. Fiorentino, N.M. Amiotti, and R.J. Vasquez. "Water Resources in the Semi-arid Pampa–Patagonia Transitional Region of Argentina." *Journal of Arid Environments* 53.2 (2003): 257-70.

"Peru's Energy Ambitions: Hydro-powered Dreams: Hopes and Fears of a Regional Energy Hub." *The Economist - World News, Politics, Economics, Business & Finance*. 10 Feb. 2011.

Platt, Jonathan L. *Economic Analysis of Dam Decommissioning*. Denver, Colorado: U.S. Department of the Interior Bureau of Reclamation, 2003.

Pochat, Victor. *The La Plata River Basin*. Water for the Americas: Challenges and Opportunities. Publication no. C1428EAJ. Buenos Aires: 7th Biennial Rosenberg International Forum on Water Policy, 2010.

"Powering Argentina's Future Energy Needs." *The New York Times* 2006, sec. Global Economies: Argentina.

"Represa Yacyretá: un delito ambiental y social." *ANRED Agencia de noticias red acción*. Agencia de Noticias Biodiversidadla, 27 May 2007. Web. 18 Oct. 2011.

Ribeiro, Gustavo Lins. *Transnational Capitalism and Hydropolitics in Argentina: the Yacyretá High Dam*. Gainesville: University of Florida, 1994. Print.

Slunge, Daniel, and Rossmary Jaldin. *Bolivia Environmental Policy Brief: Environmental Sustainability, Poverty and the National Development Plan*. La Paz, Bolivia: Environmental Economics Unit, Department of Economics, Göteborg University, 2007. Sida-EEU.

Smolders, A.J.P., G. Van der Velde, and J.G.M. Roelofs. "El Niño Caused Collapse of the Sábalo Fishery (Prochilodus Lineatus, Pisces: Prochilodontidae) in a South American River." *Short Communication* (1999): 30-32. Print.

Smolders, A.J.P., K.A. Hudson-Edwards, G. Van der Velde, and J.G.M. Roelofs. "Controls on Water Chemistry of the Pilcomayo River (Bolivia, South-America)." *Applied Geochemistry* 19.11 (2004): 1745-58. Print.

Smolders, A.J.P., M.A. Guerrero Hiza, G. van der Velde, and J.G.M. Roelofs. "Dynamics of Discharge, Sediment Transport, Heavy Metal Pollution and Sábalo (Prochilodus Lineatus) Catches in the Lower Pilcomayo River (Bolivia)." *River Research and Applications* 18.5 (2002): 415-27. Print.

Stassen, Marinke J. M., Max W. P. M. van de Ven, Tjisse van der Heide, and Gerard van der Velde, Marco Antonio Guerrero Hiza, and Alfons J. P. Smolders. "Population Dynamics of the Migratory Fish Prochilodus Lineatus in a Neotropical River: The Relationships with River Discharge, Flood Pulse, El Niño and Fluvial Megafan Behaviour." *Neotropical Ichthyology* (2010). Print.

Switkes, Glenn. "Chronic Problems at Yacyretá Dam." *International Rivers*. International Rivers Network, 13 July 2004. Web. 31 October 2011.

Switkes, Glenn. "Yacyretá Dam." *International Rivers*. International Rivers Network. Web. 16 Oct. 2011.

"The Ups and Downs of Dams." *The Economist - World News, Politics, Economics, Business & Finance*. 10 May 2010. Web. 18 Oct. 2011.

"The Yacyretá Dam." *Franz.ERN - European Rivers Network and RiverNet*. European Rivers Network. Web. 18 Oct. 2011.

Thomas, Caroline, and Darryl A. Howlett. *Resource Politics: Freshwater and Regional Relations*. Buckingham: Open UP, 1993. Print.

Tortajada, Cecilia, ed. *Women and Water Management: the Latin American Experience*. New Delhi: Oxford University, 2000. Print.

Tsikata, Dzodzi. *Living in the Shadow of the Large Dams: Long Term Responses of Downstream and Lakeside Communities of Ghana's Volta River Project*. Leiden: Brill, 2006.

"Yacireta-apipe: ¿Exige Argentina Definicion?" *Democracia* [Buenos Aires] 1 Apr. 1973: 2. Print.

"Yacyretá Hydroelectric Project." *The World Bank: Projects & Operations*. The World Bank Group, 24 Mar. 2000. Web.