

**REDUCING THE IMPACT OF  
ENVIRONMENTAL EMERGENCIES  
THROUGH EARLY WARNING AND  
PREPAREDNESS - THE CASE OF EL  
NIÑO-SOUTHERN OSCILLATION  
(ENSO)**

**CATHALAC | ACP | UM | TUAT | UNU**

**IMPACTS OF THE 1997-98 EL NIÑO EVENT IN  
PANAMA**

**Edited by:**

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## **EXECUTIVE SUMMARY :**

The administration and operation of the Panama Canal has been carried out jointly by a complex US civilian and military apparatus. To guarantee the security of the Canal, the United States received the concession of a strip of land 8 km long on each side of the Canal and of the small portion of the Chagres watershed delimiting Madden Lake. This strip of land became known as the Panama Canal Zone.

As time passed and Panama began to grow as a nation following its separation from Colombia in 1903, a new sense of nationalism developed. The Panamanians felt the need to renegotiate the American presence in the Canal Zone and, in 1977, the Torrijos-Carter Treaty was signed. Under this treaty, the United States was committed to the return of complete control of the Canal to the government of the Republic of Panama on 31 December 1999.

At present, the Panama Canal is administered by the Panamanians, and it is incumbent on the Authority of the Panama Canal (in Spanish, Autoridad del Canal de Panamá, ACP) to effectively continue to comply with the tasks for which it was built.

The Canal watershed is defined as the geographic area, the surface, and the underground waters which flow toward the Canal and are spilled into it or its tributary lakes. The borders of the watershed are defined by an imaginary line that joins the highest points of the mountains surrounding the hydrologic system of the Canal. Until 1999, the watershed was said to cover 1,289 square miles. With the passage of Law 44 of 31 August 1999, the legal territory of the hydrographic watershed was extended to include three other river basins: Rio Indio, Caño Sucio, and Coclé del Norte. All three are located to the west of Gatun Lake in the Atlantic region.

Because the Canal is not at sea level (Lake Gatun is 85 feet above sea level), the ships are elevated by a system of three sets of locks. Going from the Atlantic Ocean to the Pacific, a ship passes through the locks of Gatun, Pedro Miguel, and Miraflores. The locks are fed by water displaced only by the effects of gravity; water is not pumped into the locks. The water elevates or lowers the ships in the locks. During each transit, approximately 52 million gallons of water are used. The total water storage capacity of the Canal is approximately 1,660 billion gallons. However, the net capacity is approximately 365 billion gallons. Gatun Lake provides 203 billion gallons, and Madden Lake 162 billion gallons.

According to Article 84 of the Law of 1 July 1998, "the administration, use, maintenance, and conservation of the water resources of the hydrographic watershed of the Panama Canal will be the responsibility of the Panama Canal Authority, in coordination with the National Authority for the Environment (ANAM), and having as a basis the strategies, policies, and programs related to the sustainable management of the natural resources in these river basins."

The Panama Canal allows the passage of ships from one ocean to the other. However, the watershed that feeds this engineering marvel allowing ships to pass from one ocean to another does not escape from El Niño's effects. Studies about the effects of the El Niño-Southern Oscillation (ENSO) cycle in Panama show that there is a clear tendency during El Niño (the warm extreme) toward a reduction in precipitation below the normal long-term average values, mainly in the Pacific region or the southern part of Panama. Panama's climate has two distinct seasons: a rainy season (mid-April to mid-December) and a dry season (mid-December to mid-April).

Early studies<sup>1</sup> indicated that El Niño is associated with below-normal precipitation values. The annual mean deviation of the anomaly of precipitation during El Niño years is 8 percent below normal in the region of the Canal's watershed. In 11 of the 12 El Niño years used in the study, the precipitation anomaly is negative. There is a reduction in the net river discharge that flows into Gatun Lake during El Niño years, which causes a decrease in the lake's water level. Historical records document a considerable reduction in precipitation in the watershed during El Niño.

Consequently, there is a decrease in the levels of the lakes that feed the Canal system during El Niño. These events jeopardize the normal operation of the Canal. The Canal's operating conditions have been especially critical during the last two strong ENSO warm events of 1982-83 and 1997-98.

During extreme water shortages, the authorities responsible for the management of the Canal have been forced to implement a set of navigational draft restrictions for transiting vessels. These constraints have had adverse economic effects on some customers and users of the Canal. In addition, the fact that some of them have opted for alternate routes to transport their cargo during El Niño years has translated into a decrease in the number of ships crossing the Canal, which in turn yielded less general income from transits.

The Panama Canal Authority uses the water of the Canal according to the following distribution: 58% is used for the operation of the locks; 36% for generation of hydroelectric power, and 6% for municipal consumption.

El Niño is responsible for causing major problems to the economy of the region and, consequently, to the economy of Panama. Several socio-economic sectors in the country are affected by El Niño (and La Niña). These sectors include, but are not limited to, the following:

- Water resource and energy
- Natural resources
- Farming
- Fisheries
- Human health

According to data released by government agencies and private companies, Panama's productive sectors experienced losses of over \$50 million during the 1997-98 warm event.

The energy generated in Panama is mainly dependent on the availability of water resources. Thus, energy production depends on precipitation, which means it will be affected by El Niño. In years of extreme drought, the country has been subjected to electric power blackouts for periods of more than five hours a day for several weeks at a time. During the 1997-98 El Niño, various cities in Panama experienced daily blackouts ranging from two to four hours. In addition to the irregularities in the delivery of electric power, the population also suffered from shortages in water supply for human consumption, mainly in urban areas. And, as noted earlier, the transit of ships through the Panama Canal has been affected by El Niño events.

The most critical operating conditions that could be blamed on severe drought, observed since the Canal's construction, were registered during the El Niño events of 1982-83 and 1997-98. In fact, during the 1997-98 El Niño, the lakes of the Canal's watershed reached their lowest levels ever recorded in its history. The Panama Canal Commission, the organization in charge of Canal operations at the time, was forced to apply draft restrictions to ships in transit. During the 1997-98 event, several fires were reported in the Canal watershed. These were extinguished rapidly, mostly by the US military, and never progressed into major forest fires.

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On 10 May 1998, under a photograph of a desert-like countryside landscape, *El Panama America*, a daily newspaper, wrote that “the El Niño phenomenon has harmed farmers and Indian communities that live off the products of the land, and they have not been able to harvest a thing since last year.” About 3,861 hectares insured under Instituto de Seguro Agropecuario (ISA) were affected by El Niño.

Droughts also reduce the quality and quantity of pasture available for cattle and, therefore, affect meat and milk production. In addition, a considerable number of cattle died due to illnesses generated by water shortages. The losses were in the tens of millions of dollars. The ISA itself paid US\$1.47 million in compensation to 596 farmers and cattle raisers.

Not all crops suffered during the 1997-98 El Niño. For example, in the provinces of Chirique and Bocas del Toro, coffee growers reported an increase in production of 10,000 sacks in comparison to the previous year's yield.

In aquaculture, a decrease in shrimp production was detected, because of low survival rates and poor growth. Shrimp farming is very sensitive to changes in precipitation and air temperature. The effects of El Niño on the fisheries sector are not yet well understood. However, some observations showed a tendency toward a decrease in the number of fish landings during warm events. The cause of this trend is attributed to the anomalous increase in sea surface temperatures.

The impacts of ENSO warm events on the country's economy are most significantly experienced by the poorest sectors of the population, mainly farmers and indigenous groups. Drinking water in rural areas becomes scarce, which brings, as a consequence, an increase in the incidence of water-related and vector-borne diseases such as malaria and dengue. In many cases, the deterioration of the quality of subsurface waters, caused by infiltration from domestic and industrial sources, also aggravates health conditions. Studies carried out by researchers within the framework of the Trade Convergence Climate Complex (TC3) research initiative<sup>2</sup> also showed that during the 1997-98 El Niño, there were increases in the number of people affected by respiratory and dermatological diseases, in addition to vector-transmitted and water-borne diseases.

The Department of Meteorology and Hydrography of the Panama Canal Authority is mainly responsible for the management of water resources in the Canal watershed. This institution has an operational mandate and has not carried out specifically scientific investigations on El Niño. Nevertheless, making use of the records of physical data recorded since 1903, it has produced time series that, after being processed and analyzed, can be used to infer the effects of El Niño in the Panama Canal watershed.

The Department of Hydrometeorology of the Institute of Hydraulic Resources and Electrification (IRHE) (recently privatized under the name Electric Transmission Company, or ETESA) was responsible for monitoring the behavior of meteorological parameters in time and space. Until the early 1990s, this was the only government institution to carry out occasional studies of El Niño. These studies centered primarily on the variations of precipitation in Panama during El Niño. Beginning in 1995, studies were carried out to establish the effects of El Niño in Panama and its impact on electricity generation.

The interest in Panama about the El Niño phenomenon began to gradually increase after the warm event of 1982-83, with the few works of investigation already noted. It was not until the middle of the 1990s when the global scientific interest in this phenomenon spread throughout the continent that Panama began to involve itself extensively in ENSO-oriented research. An important role was played by the TC3 Network in the promotion of research on El Niño in

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Panama. This group of researchers from the physical and social sciences began to organize different activities aimed at evaluating the impacts of El Niño on key socio-economic sectors. These activities continue to bring together scientists and decision makers.

In the mid-1990s, Panama began to take important steps to combine the efforts of different national institutions and regional organizations to exchange experience and knowledge and, thus, to increase its understanding of El Niño and its effects and consequences in Panama. One of the first initiatives was the organization of the TC3 Network under the coordination of the Water Center for the Humid Tropics of Latin American and the Caribbean (in Spanish, CATHALAC), of the first National Forum on “The El Niño Phenomenon and Its Impacts on Panama.” This took place in November 1995.

### *The 1982-83 El Niño*

Dependent on a system of locks and a navigable lake, water is a vital element for the Canal’s operations. The El Niño event of 1982-83 caused the first important impact of an El Niño on the waterway.

The first indication of El Niño’s influence appeared in November 1982, when Gatun Lake did not increase to the level of 26.75 meters (87.75 feet) as normally occurs during that month. It was only at the beginning of February 1982, when this critical level was finally reached, and the implementation of the first restriction was put in place. It is important to remember that this El Niño was not forecast, and even as the event was developing it was not recognized as the onset of El Niño.

With the experience acquired during the 1982-83 event, the Canal Commission decided to deepen by 3 feet the navigable channel of the Canal waterway. They thought that by doing so, if another El Niño event of this magnitude were to occur again, it would not be necessary to set navigational draft restrictions, or at least they would not be as significant as those applied in 1983. Recall that the 1982-83 El Niño, at that time and until the 1997-98 event occurred, was labeled “The El Niño of the Century.” Of course, Canal operators (as well as El Niño researchers everywhere) did not expect an event of the intensity of the 1997-98 El Niño. This event has replaced the 1982-83 event as “The El Niño of the Century.” The 1997-98 El Niño restrictions were estimated to have cost US\$12 million to the Panama Canal coffers.

Unlike the 1982-83 El Niño, the 1997-98 event was forecast some months ahead of its impacts on Panama. This allowed the Panama Canal Commission to take some preventive measures aimed at mitigating any adverse effects that this event could cause to the waterway. The initial prognosis indicated that this El Niño would be of considerable intensity.

The information about the possible onset of an El Niño was received by the personnel of the Office of Meteorology and Hydrology of the Panama Canal Commission (PCC) in April 1997 through the Internet. Around the middle of that year, PCC officials consulted Web sites and obtained information indicating that it would be a strong event. The main source for these consultations was the NOAA Web site postings. The information was presented in numerical, graphical, and tabular form and as text and images. The Division of Public Affairs of the PCC also received information on the development of this event through different media (e.g., TV reports, email messages).

The first news disclosed by the print media on the matter of a warm event occurred on 1 June 1997 through an international news posting from Tegucigalpa, Honduras, entitled “El Niño Returns With Its Pranks,” published in the newspaper *La Prensa*. The first news on the possible effects of the event in Panama was published in the newspaper *El Panama America* on 10 June 1997, with the headline, “El Niño Phenomenon Will Cause Losses.” Nine days later, a group of experts in the region, participants of the TC3 Network, met in Panama City. They included in their

agenda an analysis of the state of the event's development. The conclusions they formulated with respect to El Niño were disseminated by way of the local mass media.

The first news that suggested possible effects of the 1997-98 El Niño event on the Canal watershed was published 17 August 1997 in *La Prensa* under the title, "El Niño Could Affect the Canal."

PCC employees from several departments organized a Working Group that met regularly to coordinate efforts before the imminent impact of El Niño. Participants in these meetings included representatives of the Division of Engineering of the Meteorology and Hydrology branch, the Department of Marine Operations, the Department of Engineering Services, and the Division of Public Relations of the PCC. A series of recommendations from these meetings were provided about the actions to be implemented by the different departments of the PCC. The outcomes of these meetings were reported to the corresponding authorities, who then approved the execution of the recommended actions.

The Department of Marine Operations continuously sent warnings to the ships (users and customers of the Canal) to inform them of the situation with regard to Canal operations. Special emphasis was given to inform them clearly about the status of draft restrictions. Twenty-two warnings of navigational restrictions in relation to the ENSO event were sent out during 1998. As a result of the imposed draft restrictions, the number of ships passing through the Canal decreased by 4% during the second trimester of 1998 in relation to the previous year.

From May to December 1997, which happen to be the months of expected intense rains in the watershed, recorded precipitation was significantly below average. That year, the Canal watershed experienced its worst recorded drought in Panama Canal history. The existing climatic conditions caused a reduction of 25% in the runoff toward the tributary lakes of the Canal. In spite of a decrease of 58% of the water flow toward Gatun Lake, by the end of September and into the month of October, the authorities of the Canal officially announced that the operations in the Canal would NOT be affected for the remainder of 1997.

The forecasts by PCC experts in the first months of 1998 were not very encouraging. Based on the experience of the 1983 event, draft restrictions were forecast to begin in February 1998, in light of the possibility that the lake levels would be unable to recover because of the fact that the dry season was already approaching.

Measures were taken to mitigate the effects of this event, and to avoid the negative impacts that would affect the customers and users of the Canal, as well as the public in general. The measures taken were as follows:

- Saving water by stopping the generation of hydroelectric power at the Gatun plant, and replacing the lost electric power by the more expensive thermoelectric generation. (The Gatun plant is used only when there is an excess of water in the lake, because it would otherwise spill its water directly into the sea.)
- Saving water by using smaller chambers of suitable size.
- Saving water by means of ship transit in tandem through the locks (more than one ship per lock).
- Saving water by means of crossed water transference between adjacent chambers.
- Maintenance of a safe depth in the navigable channel of the Canal through the implementation of nearly continuous dredging.

The implementation of these measures cost US\$10 million to the Canal authorities, but at the same time they brought about a water savings of about 10 to 15 percent. Another adopted action was to make a complete sounding of the bottom of the Canal section known as Corte Culebra, which would serve to guide the dredging of this section. This helped to eliminate all accumulated sediment and reduced the degree of draft restrictions.

The various measures that were adopted, together with the continuous monitoring of important hydrometeorological parameters for the Canal watershed, allowed for a delay in the setting of draft restrictions. Originally, it was believed that draft restrictions would need to be set by the end of February 1998. But it was not until 12 March 1998 that the Canal authorities issued the first of their 22 warnings announcing El Niño-related draft restrictions. These warnings were issued to the users with an average of three weeks in advance of their implementation.

On 12 March 1998, months after the implementation of the measures for water conservation, the first draft restriction was applied. This fact was beneficial to the customers who traversed the Canal from the end of February to 11 March, enabling them to transport more cargo than would be the case after 12 March. The maximum allowed draft in the Panama Canal was decreased to 39 feet, half a foot less than the maximum allowed draft under normal conditions. Obviously, some customers were affected by these restrictions. A reduction in draft of half a foot, depending on the type of ship, could represent a loss of lift capacity of up to several hundred tons of cargo.

The maximum allowed draft was reduced by a half-foot every time a restriction was set, until it reached a minimum value of 35.5 feet on 19 April 1998. This draft restriction stayed in place until 28 April, when the maximum allowed draft was increased with the coming of the rains that began to fall primarily in the Atlantic sector of the watershed. Progressively, as rain accumulated over the Canal watershed, the draft was increased until it returned to its normal value of 39.5 feet on 29 July 1998.

Fortunately, some of the earlier forecasts related to draft restrictions were not correct, such as the one that predicted that the maximum allowed draft would be reduced to 33.5 feet in May 1998. If this had occurred, it would have further affected the customers and users of the Canal. On 25 August 1998, the PCC reported the Canal lake levels had returned to normal.

During the period of draft restriction, some customers of the Panama Canal had the chance to decide on alternative routes like the North American coast-to-coast railroad or the Suez Canal. Some Canal economists were afraid that the programmed increase in tolls by the PCC for January 1998 would have a negative impact on the international marine community and would affect the volume of traffic through the Panama Canal. This increase was programmed before awareness of the appearance of the El Niño for the purpose of gathering funds to finance extension works in Corte Culebra.

The interruption of the generation of hydroelectric energy at the Gatun hydroelectric plant in order to save water had an adverse effect on the Panama Canal. The PCC was deprived of between US\$5 million and US\$8 million, which would have been generated by the sale of this energy.

In spite of the negative effects of the 1997-98 El Niño, such as the drought in the Panama Canal watershed caused by a reduction in precipitation of almost 35%, and the investment of about US\$12 million that the PCC had to make to mitigate these effects, the income obtained by the PCC not only fulfilled the projected expectations for that fiscal year (October 1997 to September 1998), but surpassed them. The income (US\$743 million) was an increase of 10.6% over the previous year's income (US\$663.9 million). This success, according to declarations of the PCC authorities, was possibly due to several factors. One of these, and possibly the most important, was the capacity of the personnel to plan and implement actions to counteract the critical climatic conditions in the region that were created by the 1997-98 El Niño. Other factors included the adoption of new tariffs for tolls in 1997 and 1998, the increase in traffic of ships of greater width in the Canal, and other services that the Canal offered.

Although the Panama Canal could, through successful management, face one of the hardest contingencies ever experienced, the 1997-98 El Niño is still considered the most intense event of the last 150 years. Various customers and users were affected during the four-and-a-half months of draft restrictions. The ships that were affected were mainly those carrying bulky loads, tankers,



and other container carriers. Between 12 March and 20 May 1998, 2,612 transits occurred, and of these, 289 ships (11%) had to reduce their drafts to be able to go across the Canal. This was a low percentage, according to the Canal authorities. Some of those ships, having to reduce their draft, experienced a loss of lifting capacity of up to a thousand metric tons for each half-foot of draft restricted. These restrictions obviously affected their economic gain. For example, from 12 March to 16 April, 1,375 ships passed through the Canal, and of these 138 were affected by the draft restrictions and were forced to reduce their cargo by approximately 500,000 metric tons. This caused the Canal authorities to consider deepening the waterway by a few feet more, as had been done in 1984.

With the approval of the new Law 44 of 31 August 1999, the legal area of the hydrographic watershed was extended to include three other river basins, namely Rio Indio, Caño Sucio, and Coclé del Norte, all three of which are located to the west of Gatun Lake in the Atlantic region. The annexation of these three river basins to the Canal system, together with the proposed structural modifications of the waterway, will provide new elements to be considered when modeling the potential impacts of future ENSO warm and cold events on the Panama Canal. Research on the impacts of climate variability still needs to be carried out in parallel with the future development of the Panama Canal system.

### *Conclusion*

The Canal authorities do not have the resources to forecast El Niño events and, therefore, it depends on the information that it acquires from international institutions that forecast and monitor the ENSO cycle. The different experiences gained during the El Niño events of 1982-83 and 1997-98 highlight the importance of obtaining early warning of these events to guarantee better management of the watershed's resources. It is not difficult to imagine what might have happened to the operations of the Panama Canal during the 1997-98 event if in 1984 the Canal authorities had not decided to further deepen the navigable channel of the Canal or if the forecast of the 1997-98 event had been delayed.

Newspaper, radio, television, and other forms of media are important channels through which to disseminate information about climatic events. They are also important forces that can either contribute to the mitigation of the impacts of such events by alerting the opinions of the general public, or can cause unnecessary unrest (even hysteria) when the intensity of the event is exaggerated. In the case of the 1997-98 El Niño, the media did not influence the decisions or actions undertaken by the PCC with regard to the waterway. The PCC conducted its business based on its experiences during the 1982-83 El Niño, and its interpretation of information coming from sources such as NOAA. As a matter of fact, the local media generally based its coverage of the situation as it related to the Panama Canal on press releases issued by the PCC's Office of Public Affairs. This was not the case in relation to other sectors, such as agriculture, where speculation from some media agencies sometimes ran wild.

In general, the treatment of the 1997-98 El Niño by the local media was relatively professional. The reason for such moderate reporting on the effects of the 1997-98 El Niño in Panama could be that enough catastrophic footage of impacts was coming in from Peru and Ecuador, and later from Honduras (after the passage of Hurricane Mitch), that there was no need to exaggerate the situation. Thus, the media could have "attractive" headlines.

In summary, as stated by the PCC Administrator, Alberto Aleman Zubieta, the rapid response of the Canal's authorities to the 1997-98 El Niño demonstrated their capacity to handle major problems. The action plan implemented in response to this extreme climatic event was based on the interpretation of information coming from adequate sources such as NOAA, enhanced by input provided by local experts, and the expertise gained by the PCC during the 1982-83 event. However, the continuous and accelerated changes in land use that are taking place in the Canal

watershed calls for a permanent monitoring of the basin and a constant verification of the models that simulate the response of the Canal system to climate variability.

### **Lessons Learned**

- In preparation for a future major El Niño event, the Panama Canal Authority needs to guarantee good storage and provision of water for the watershed. The best solution seems to be the expansion of the Canal watershed system to include other basins along with the possible construction of new dams.
- During extreme water shortages, such as those generated during the 1997-98 El Niño event, a contingency plan needs to be put in place that should include a good efficient management of water resources that take into account the different water usages. (This is being put together now.)
- To promptly and adequately take the necessary measures to minimize impacts in ship transits and to inform the shipping industry with sufficient advance notice on these measures, the Panama Canal Authority needs to identify a mechanism in order to have available as early as possible forecasts of the onset of a warm event. (This is being undertaken at present.)
- The available studies on the impacts of El Niño on the watershed were good benchmarks for the Canal Authority to put together a strategic plan during the 1997-98 El Niño, but not sufficient, taking into consideration the continuous and accelerated changes in land use that are taking place in the Canal's watershed. This calls for a permanent monitoring of the basin and a constant verification of the models that simulate the response of the Canal system to climate variability. In other words, we need to do more research.

### **INTRODUCTION :**

Studies made on the effects of El Niño/Southern Oscillation (ENSO) phenomenon in Panama show that there is a clear tendency towards a reduction in precipitation below its normal long-term average values, mainly in the regions of the Pacific or southern part of Panama. The Panama Canal allows the passage of ships from one ocean to the other. However, the watershed that feeds this engineering marvel allowing ships to pass from one ocean to another does not escape from ENSO effects.

Historical records document a considerable reduction in precipitation in the watershed during the occurrence of ENSO warm events, or El Niño. Consequently, there is a decrease in the levels of the lakes that feed the Canal system. These events jeopardize the normal operation of the Canal (Vargas, 1995). The Canal's operating conditions have been specially critical during the last two STRONG warm events of 1982-83 and 1997-98.

During extreme water shortages, the authorities responsible for the management of the Canal have been forced to implement a set of navigational draft restriction for transiting vessels. These constraints have adversely affected economically some customers and users of the Canal. In addition, the fact that some of them have opted for alternative routes to transport their cargo during El Niño years has translated into a decrease in the number of ships that cross the Canal, which in turn yielded less general incomes, from transits (Sucre, 1997).

The expansion of the Canal watershed system along with the possible construction of new dams seems to be the best solution to guarantee a good storage and provision of water for the watershed. But for these measures to have success, they must go accompanied by a good efficient management of those water resources as well as by early forecasts of the onset of warm events.

## **THE PANAMA CANAL :**

### *History*

The Panama Canal, described as one as most important works of engineering in the world, was inaugurated on August 15, 1914. This complex structural system allows the passage of ships between the Atlantic and the Pacific oceans, considerably reducing shipping distances between nations around the globe. Before the construction of the Panama Canal, the Straits of Magellan around the southern tip of South America was the route used to go from one ocean to the other. This sea route not only took much more time, but in addition it was a very dangerous journey.

Many powers were interested in the construction of a route through some narrow portion of the American continent that would expedite communication between countries bordering either ocean. This idea goes back to the time of the conquest of the continent by the Spaniards in the 1500s. It was not until 1878, however, that a formal agreement was reached in Paris, between France and Colombia, to carry out the construction of an inter-oceanic sea level Canal that would cross the Central American Isthmus (Castillero, 1962). The task of directing such enterprise was given to Fernando de Lesseps, the man who had been in charge of constructing of the Suez Canal.

However, difficulties in the administration and company organization as well as health problems forced the interruption of the Canal's construction in 1890. The construction company was cited to appear before the French courts, and eventually had to declare bankruptcy. Four years later, a new European company resumed the work, but they too could not advance much, and ended up transferring its rights to the United States of North America in 1899 (Castillero, 1962).

The building of the Canal by the United States did not start without major changes in the regional political arena. At the time, the Isthmus of Panama was but an administrative department of Colombia. To make official the construction of the Canal by the US, the Herrán-Hay treaty was put forward on January 22, 1903. However, the Colombian Senate did not agree with the wording of the document, and rejected the treaty on the basis that it was harmful to the sovereignty of Great Colombia (Castillero, 1933). This situation motivated the United States to promote and support the separation of Panama from Colombia. On November 3, 1903, the Isthmus of Panama declared its independence. Fifteen days later, the government of the newly established Republic of Panama and the United States signed the Hay-Bunau Varilla treaty which was based on the same conditions that had the previously rejected by Colombia Herrán-Hay treaty.

Analyzing the various problems that faced the companies that had previously tried to carry out the construction of the Canal, the United States decided to build a waterway with locks. In addition, they were well organized, administratively and technically. But most important, the US had the means to mitigate the existing sanitary problems in the region, such as yellow fever, that had caused the loss of several thousands of human lives during previous construction attempts. Having overcome all of the difficulties that a work of this magnitude presented, the Panama Canal was finally inaugurated by the government of the United States in mid-August 1914.

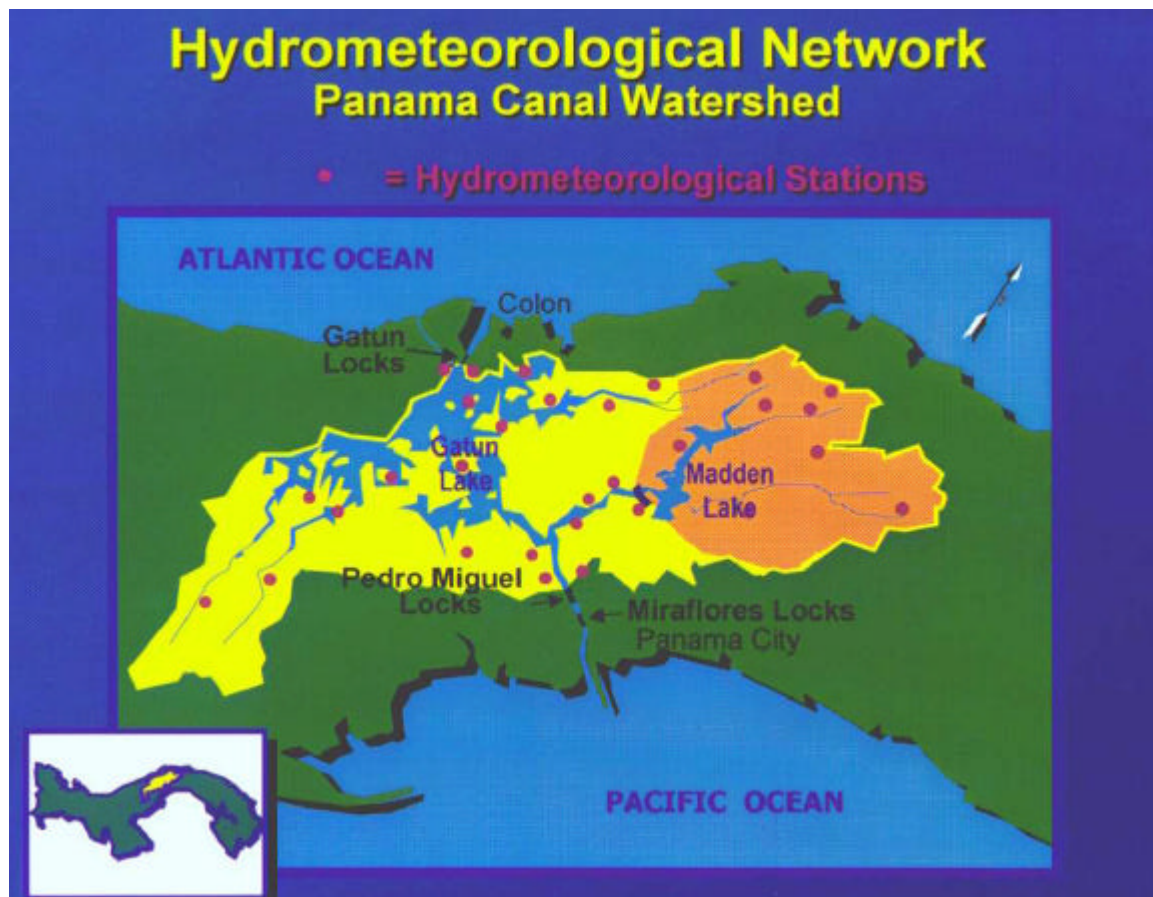
The administration and operation of the Panama Canal was carried out jointly by a complex US civilian and military apparatus. To guarantee the security of the Canal, the United States received the concession of a strip of land eight kilometers wide on each side of the Canal and of the small portion of the Chagres watershed delimiting Madden Lake. This strip of land was to be known as the Panama Canal Zone.

As time passed, and Panama began to grow as a nation, a new sense of nationalism developed. The Panamanians felt the need to re-negotiate the American presence in the Canal Zone. This motivated the formulation of new agreements between both nations. After almost seventy-five years of symbiosis, interrupted frequently by periods of great tension between the “zoneans” and the Panamanians and the consequent cycles of unstable diplomatic relations, in 1977 the Torrijos-Carter treaty was signed. Under this treaty, the United States was committed to return to the Government of the Republic of Panama the complete control of the Canal on the December 31, 1999.

The repatriation of the Canal Zone to Panama has just taken place. At present, the Panama Canal is administered by the Panamanians and it is incumbent on the Authority of the Panama Canal (in Spanish, Autoridad del Canal de Panamá, ACP) to effectively continue to comply with the tasks for which it was built.

### *The Panama Canal Hydrographic Watershed*

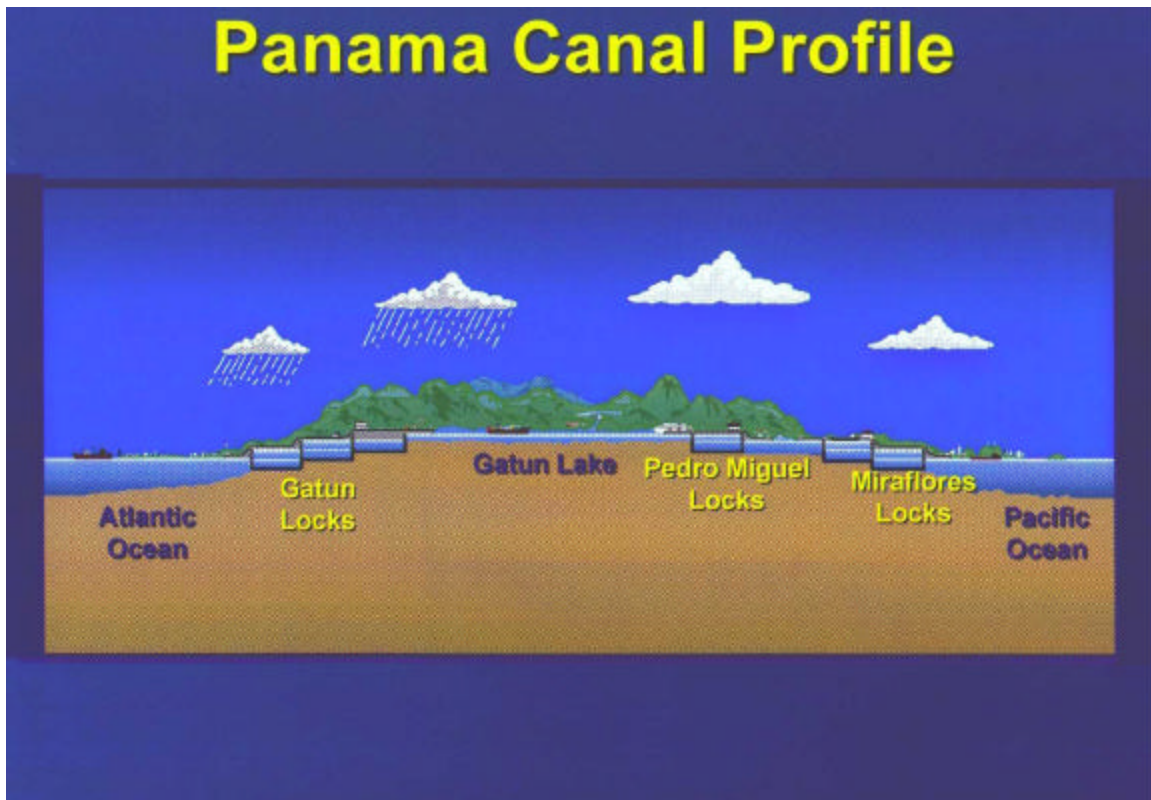
The Canal watershed ([see Figure 1](#))



is defined as the geographic area, the surface and underground waters which flow toward the Canal and/or are spilled into it or into its tributary lakes. The borders of the watershed are defined by an imaginary line that joins the highest points of the mountains that surround the hydrologic system of the Canal. Until 1999, the watershed was said to cover 1,289 square miles. With the approval of the new Law 44 of August 31, 1999, the legal territory of the hydrographic watershed was extended to include three other river basins, namely Rio Indio, Caño Sucio and Coclé del Norte, all three located to the west of Gatun lake in the Atlantic region (Donoso and Adames, 2000).

The Madden dam divides the Canal watershed into 2 different regions: 1) the upper basin to the east of the navigation channel, which includes Madden Lake and its tributaries - the Chagres, Pequení and Boquerón rivers; and 2) the lower basin, which consist of main Gatun Lake and its tributaries, the Gatun rivers, Ciri Grande and Trinidad. The upper basin is a region of mountain land and dense forests. The lower basin region is conformed of small hills and smooth slopes.

The Canal not being at sea level (lake Gatun is 85 feet above sea level), the ships are elevated by a system of three sets of locks. Going from the Atlantic Ocean towards the Pacific, a ship passes the locks of Gatun, Pedro Miguel and Miraflores, [\(see Figure 2\)](#).



The locks are fed by water displaced only by the effects of gravity; water is not pumped into the locks. The water elevates or descends the ships in the locks. During each transit, approximately 52 million gallons of water are used. The total water storage capacity of the Canal is of approximately 1,660 billions of gallons. However, the net capacity is of approximately 365 billions of gallons. The Gatun Lake provides 203 billions of gallons, and the Madden Lake 162 billions of gallons.

According to Article 84 of the Law of July 1, 1998, "the administration, use, maintenance and conservation of the water resources of the hydrographic watershed of the Panama Canal, will be the responsibility of the Panama Canal Authority, in coordination with the National Authority for the Environment (ANAM, in Spanish), and having as a basis the strategies, policies and programs related to the sustainable management of the natural resources in these river basins".

The Authority of the Panama Canal uses the water of the canal watershed according to the following distribution: 58 percent for the operation of the locks, 36 percent for the generation of hydroelectric power, and 6 percent for municipal consumption (C. Vargas, pers. comm., 1999).

### ***General Overview of the Hydrologic Cycle in the Panama Canal Watershed***

The climate of the region is characterized as tropical. Both, temperature and humidity are relatively high throughout the year, and precipitation is abundant. There is a clear seasonal variation in the time distribution of precipitation. The dry season normally begins around December and lasts approximately 4 months, whereas the rainy season covers the rest of the year (approximately 8 months).

The annual mean precipitation for the stations in the Canal watershed vary between a maximum of more than 3,300 mm (130 inches), on the Atlantic coast, to a minimum of approximately 1,500 mm (60 inches), in the Pacific coast. In general, for the entire watershed, the annual mean precipitation from climatology for a period of 10 years (1985-1994) is 2,596 mm (102 inches). The stations located in the Madden Lake report an annual mean precipitation generally higher than that reported by the stations located in the area downstream of the Madden dam.

High winds usually occur during the floods season, and tend to extend from September to the beginning of January. Maximum winds are predominantly from the northwest with an average speed of approximately 12.9 Km/h (8 mph). The maximum gusts are generally smaller than 48 km/h (30 mph), and are usually associated with thunderstorms.

The run-off distribution in the Panama Canal watershed is seasonal, extremely variable, and follows the same pattern as the precipitation. Beginning around May, the run-off begins to increase until October and November (normally the months of maximum run-off), and diminishes gradually during the dry season, from December through April. The Madden Lake sub-basin is a more productive region in terms of water resources availability than the sub-basin downstream of the Madden dam. Although the area of the sub-basin of Madden only represents approximately 31 percent of the total area of the Hydrographic Canal watershed, the water contributed by this region adds to 45 percent of the total run-off of the basin.

As was indicated earlier, the annual mean precipitation from climatology at the Panama Canal watershed is 2,596 mm (102 inches). The water losses in the watershed due to infiltration, evapotranspiration processes in plants, and other external factors, are considered to be around 41 percent, that is to say, 1,061 mm (42 inches). Therefore, the gross amount of water that manages to store itself in the lakes is only 59 percent of the total annual rainfall that is approximately 1,535 mm (60 inches). Of this accumulated gross amount of water stored in the lakes, approximately 11 percent, equivalent to 174 mm (7 inches), is lost by the effects of direct evaporation from the surface of the Gatun and Madden lakes. The remainder 89 percent, 1,361 mm (53 inches), constitutes the net run-off.

## **EL NIÑO AND LA NIÑA :**

### ***The Influence of El Niño and La Niña In Panama***

Panama's climate presents two distinct seasons, a rainy season (mid-April to mid-December), and a dry season (mid-December until mid-April). The climatic events known as El Niño and La Niña have ample repercussion in Panama. Both are characterized mainly by the alterations that they cause to the regional precipitation patterns (Donoso and Bakkum, 1998)

El Niño is the more studied of the two ENSO extremes, mainly because its effect on the country is more widespread than that of its counterpart La Niña. Therefore, more information exists related to El Niño than to La Niña. Depending on its intensity, El Niño usually causes below normal precipitation in Panama, mainly on the Pacific side of Panama. When a La Niña of considerable intensity occurs, precipitation in Panama tends to be above normal. Floods tend to accompany strong La Niña events. The intensity and duration of the deficit or excess of rain in the country is highly correlated with the intensity of the ENSO extreme event.

El Niño and La Niña are responsible for causing major problems to the economy of the region, and consequently to the economy of Panama. The appearance of these events affects not only the economy of

the country, but also the life of its inhabitants (Comision Interinstitucional ENOS, 1997). Several socio-economic sectors in the Republic of Panama are affected El Niño or La Niña. These sectors include but are not limited to the following (CATHALAC, 1995):

- The Water Resources and Energy Sector
- The Natural Resources Sector
- The Farming Sector
- The Fisheries Sector
- The Human Health Sector

According to data released by government agencies and private companies, the productive sectors experienced losses of over \$50 million during the warm event of 1997-98 (Bouche, 1998).

### **Water Resources and Energy Sector**

The energy generated in Panama is mainly dependent on water resources availability; consequently, it depends on precipitation. Therefore, energy generation is affected by El Niño. In years of extreme droughts, the country has been subjected to blackout periods of more than five hours each day for several weeks (D. Farmun, pers. Comm., 1999). During the 1997-98 El Niño, various cities of Panama experienced blackout periods ranging from two to four hours (Cajar, 1998[a]). In addition to the irregularities in the delivery of electric power supply, the population also suffers from shortages in water supply for human consumption, mainly in urban areas. Equally, the transit of ships through the Panama Canal has been affected by El Niño (Vargas, 1997). The most critical operating conditions due to drought observed since its construction were registered during the events of 1982-83 and 1997-98. During the 1997-98 El Niño, the lakes of the Canal watershed reached their lowest levels ever recorded in history. The Panama Canal Commission, the organization in charge of the operation of the Canal at the time, was forced to apply draft restrictions to ships in transit (M. Morris, pers. comm., 2000).

Conversely, La Niña favors greater generation of hydroelectric power, because of the considerable increase in the amount of rain. However, extreme events have also caused problems. For one, the intense and continuous rains can jeopardize the dams that form part of the Canal system. Also, the necessity to spill the excess waters can put in danger areas vulnerable to floods. Most critical are areas populated by communities which tend to expand in the direction of the rivers, and can thus be exposed to suffer great losses.

### **Natural Resources Sector**

During the dry season our country is periodically affected by forest fires. These fires not only harm the forests, but also destroy the biological diversity of the region. This situation becomes more critical in the presence of El Niño (Diaz, 1998). Over most of the last century, the Panama Canal watershed was considered part of the "Canal Zone", and was maintained under strict military surveillance. Very few trespassed beyond the barb-wired fences that bordered "La Zona" (term used by the Panamanian to refer to the Canal Zone). Forest fires in this area were totally due to natural causes, lighting mostly.

Upon returning the Canal Zone territory to the Republic of Panama (December 31, 1999), the Authority of the Panama Canal was given the task to protect the watershed. This institution does not have the capability of the US Armed forces to control trespassers. Therefore, the possibility of having big forest fires during the next El Niño drought has increased exponentially. Already during the 1997-98 warm event, several fires were reported in the Panama Canal watershed. These were put out rapidly, mostly by the US military, and never progressed into major forest fires.

### **Farming Sector**

During intense El Niño events, the farming sector is one of the most affected. Severe droughts cause poor crops production (rice, corn, and beans, mainly). In May 10, 1998, under a photograph of a desert-like countryside, the Panama America daily newspaper wrote " El Niño phenomenon has harmed farmers and

Indian communities that live out of the products of the land, and have not been able to harvest a thing since last year” (El Panama America, 10 May, 1998). Some 3,861 Ha insured under ISA (Instituto de Seguro Agropecuario) were affected by El Niño. The most impacted crop was the tomato. Around 48% of the losses experienced in the agriculture sector were attributed to tomato plantations (Rosales, 1998). Another important crop affected was rice. In the provinces of Herrera, Coclé and Veraguas, the Ministry of Agriculture Development granted US\$247,000.00 indemnification to over 233 rice-farmers (Muñoz, 1998).

Droughts reduce the quality and quantity of pasture available for cattle, and therefore affects the meat and milk production. In addition, considerable amount of cattle die due to illnesses originated by the shortage of water. The losses are considered in the tens of millions of dollars. Only ISA itself paid 1.47 millions of US dollars compensation to 596 farmers and cattle raisers.

But not all crops suffer because of El Niño. In the provinces of Chiriqui and Bocas del Toro, coffee growers reported a production increase of ten thousand sacs in comparison to last year’s yield (Bocharel, 1998).

In aquaculture, a decrease in shrimp production is detected, due to low survival rates and poor growth. Shrimp farming is very sensitive to changes in precipitation and in air temperature.

During extreme cold events or La Niña, many crops are also affected. This can occur because the planting season is delayed, or simply because the rain is so abundant that it “drowns” the plants.

### **Fisheries Sector**

The effects of El Niño and La Niña in the Fisheries sector are not yet well understood. However, some observations show a tendency toward a decrease in the number of landings, during warm events. The cause of this trend is attributed to the anomalous increase of the sea surface temperatures (SST). Some local species such as *pargo* and *cherna* migrate to deeper waters when the SST increase. This migration makes it difficult for local fisherman to reach the schools of fish in their indigenous weak fishing boats. By mid-August 1997, the decrease in fish catchments had affected 95% of the Pedesi district fishing industry (Cortes, 1997; El Panamá América, 1997).

In addition, the salinity of water in shallow inshore coastal areas is also altered during ENSO events. A substantial decrease in precipitation or the abnormal extension of the dry season can cause considerable increase of the salinity of shallow near-shore coastal waters, such as delta areas. These changes in the properties of sea water contributes to the migration of numerous species, and consequently to the alteration of their biological (reproductive) cycles.

### **Human Health Sector**

The impacts of ENSO warm events on the country’s economy is most significantly experienced by the poorest sectors of the population, mainly farmers and natives. Drinking water in rural areas becomes scarce, which brings as a consequence an increase in the incidence of water-related diseases. As stated by Arturo Sanchez, member of the Climate Change working group for Central America, the presence of EL Niño conditions result in “an increase in insect and vector transmitted diseases, such as dengue and malaria” (La Prensa, April 1, 1998). In many cases, the deterioration of the quality of subsurface waters caused by infiltration from domestic and industrial sources can aggravate the health scenario. Studies carried out by researchers within the framework of the Trade Convergence Climate Complex (TC3) research initiative also showed during El Niño 1997-98 an increases in the number of people affected by respiratory, dermatological, and vector transmitted diseases such as hepatitis, diarrhea, and dermatitis, among other (Castro, 2000). According to government health agencies, 53,683 families were treated for different illnesses related to the 1997-98 El Niño (Castillo, 1999).

Not much research has been done on the impacts of La Niña events on the general health conditions of the population. However, excessive rains and consequent floods are deemed to affect the incidence of certain health problem, such as leishmaniasis, mainly in places susceptible to floods or water stagnation.



### *Level of Scientific Investigation on El Niño in Panama*

The Department of Meteorology and Hydrography of the Panama Canal Authority is mainly responsible for the management of water resources in the Canal watershed. This institution has an operational mandate, and has not carried out specifically scientific investigations on El Niño (M. Morris, pers. comm., 2000). Nevertheless, making use of the records of physical data registered over the years since 1903, they have produced time series that after being processed and analyzed can be used to infer the effects of El Niño in the Panama Canal watershed.

The Department of Hydrometeorology of the Institute of Hydraulic Resources and Electrification (IRHE, in Spanish), recently privatized under the name Electric Transmission Company (ETESA, in Spanish), was responsible for monitoring the behavior of meteorological parameters in time and space. Until the early 1990s, this was the sole government institution to carry out sporadic studies of El Niño. These studies were centered mainly on the variations of the precipitation in Panama during warm events. In 1995, a study was carried out aiming to establish the effects of El Niño in Panama, and its impact on the generation of electric energy (CATHALAC, 1995).

Another government institution, the Department of Agricultural Meteorology of the National Authority for the Environment (ANAM) carried out a study on the precipitation regime in Panama. This study was of much value in dealing with the 1997-98 El Niño event although it was not its main goal. This institution also started to work on an evaluation of the impacts of the El Niño on the natural resources sector (C. Castillo, pers. comm., 1999).

At some universities of the country, evaluations have been made on the influence of the El Niño phenomenon in several production sectors. Studies on the influence of climate variability on certain crops have been carried out by the Institute of Agricultural Research (IDIAP) of the Ministry of Agriculture Development.

The interest in Panama on the El Niño phenomenon begins to arise after the warm event of 1982-83, but very timidly, with few works of investigation as it were already indicated. It is not but until the middle of the decade of the 90, when a global scientific interest for this influential phenomenon is spread throughout the continent, that Panama begins to involve itself intensively in ENSO oriented research. An important role in promoting and carrying out research on El Niño in Panama is being played by the Trade Convergence Climate Complex Network (TC3). This group of researchers from the physical and social sciences begin to organize different activities aimed to evaluate the impacts of El Niño on crucial socio-economic sectors. These activities bring together scientists and decision-makers. In the mid 90's, Panama starts to take important steps to combine efforts between different national institutions and regional organizations to exchange experiences and knowledge and thus to increase the understanding of El Niño and its effects and consequences in Panama. One of these first initiatives was the organization by the TC3 Network, under the coordination of the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC), of the First National Forum " The El Niño Phenomenon and its Impact in Panama " which took place in November 1995. Many national organizations participated in the Forum, including personal of the Meteorology and Hydrography Branch of the Panama Canal Commission, as well some international institutions.

In 1996, the TC3 Network join forces with the Inter-American Institute on Climate Change Research (IAI) to further strengthen research efforts on El Niño. In August 1996, the forum "El Niño Phenomenon and its impact in the Socio-Economics Activities in the Central Provinces of the Republic of Panama " was carried out under the partnership of IAI, TC3 and CATHALAC (CATHALAC, 1996[a]). Other activities followed, such as the forum "El Niño phenomenon and its impact in the Socio-Economics Activities of Chiriqui and Bocas del Toro" in October of 1996 (CATHALAC, 1996[b]), and the workshop "The Impact of the Phenomenon of El Niño on the Biological Systems of Central America " in December of 1997 (CIFLORPAN, SENACYT, OEA, CATHALAC, CIUDAD DEL SABER, 1997).

At present, research on the impacts of climate variability in Panama by the TC3 Network of scientists continues in collaboration with the IAI and other regional organizations.

### ***El Niño and Its Impact on the Gatun Lake Level***

Historical studies and meteorological records give support to the effects of El Niño on the precipitation patterns of the country. Early studies made by Estoque *et al.* (1985) indicate that El Niño is associated with below normal precipitation values. The annual mean deviation of the anomaly of the precipitation during the years of the warm events is 8 percents below normal in the region of the Canal watershed. Table 1 presents the anomalies in percentage of precipitation for El Niño years according to Estoque *et al.* (1985). It can be observed that in 11 of the 12 years of warm events, the precipitation anomaly is negative. It can also be observed (Figure 3) that there is a reduction in the net river discharge contributing to the Gatun Lake during El Niño years, which implies a decrease of the lake level. The run-off is expressed in millions of cubic feet (MCF).

**TABLE 1**  
**RANKED ANOMALIES OF ANNUAL RAINFALL**  
**(STATIONS IN THE AREA OF THE CANAL)**

No.	Anom. %	Year	Ocurrence*	No.	Anom. %	Year	Ocurrence*
1	-30	1976	0	28	-1	1953	0
2	-27	1930	0	29	-1	1965	0
3	-24	1982	0	30	-1	1941	0
4	-20	1940	+1	31	0	1945	
5	-17	1948		32	+1	1959	
6	-16	1957	0	33	+2	1931	+1
7	-15	1980		34	+4	1963	
8	-15	1958	+1	35	+5	1934	
9	-15	1947		36	+5	1943	
10	-14	1977	+1	37	+5	1967	
11	-12	1946		38	+6	1932	0
12	-10	1939	0	39	+6	1952	+1
13	-10	1936		40	+7	1949	
14	-10	1968	-1	41	+8	1975	-1
15	-10	1979		42	+9	1942	+1
16	-10	1974		43	+9	1955	
17	-9	1971	-1	44	+11	1944	
18	-9	1983	+1	45	+12	1954	+1
19	-7	1972	0	46	+13	1950	-1
20	-7	1964	-1	47	+13	1956	-1
21	-7	1961		48	+18	1937	
22	-7	1933		49	+20	1966	+1
23	-6	1973	+1	50	+21	1938	-1
24	-5	1978		51	+26	1981	+1
25	-4	1962		52	+28	1970	-1
26	-3	1969	0	53	+36	1935	
27	-2	1951	0				

\* 0 = Year of El Niño  
+ 1 = The year after El Niño  
- 1 = The year before El Niño

**Figure 3**  
**NET CONTRUBTION TO GATUN LAKE**  
**(MCF)**

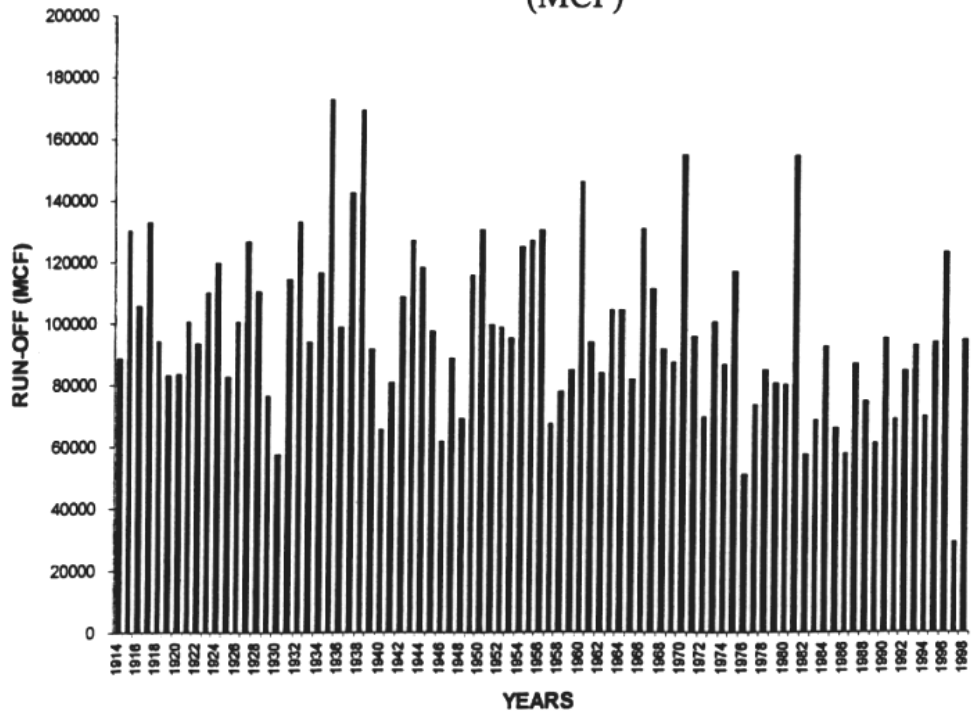
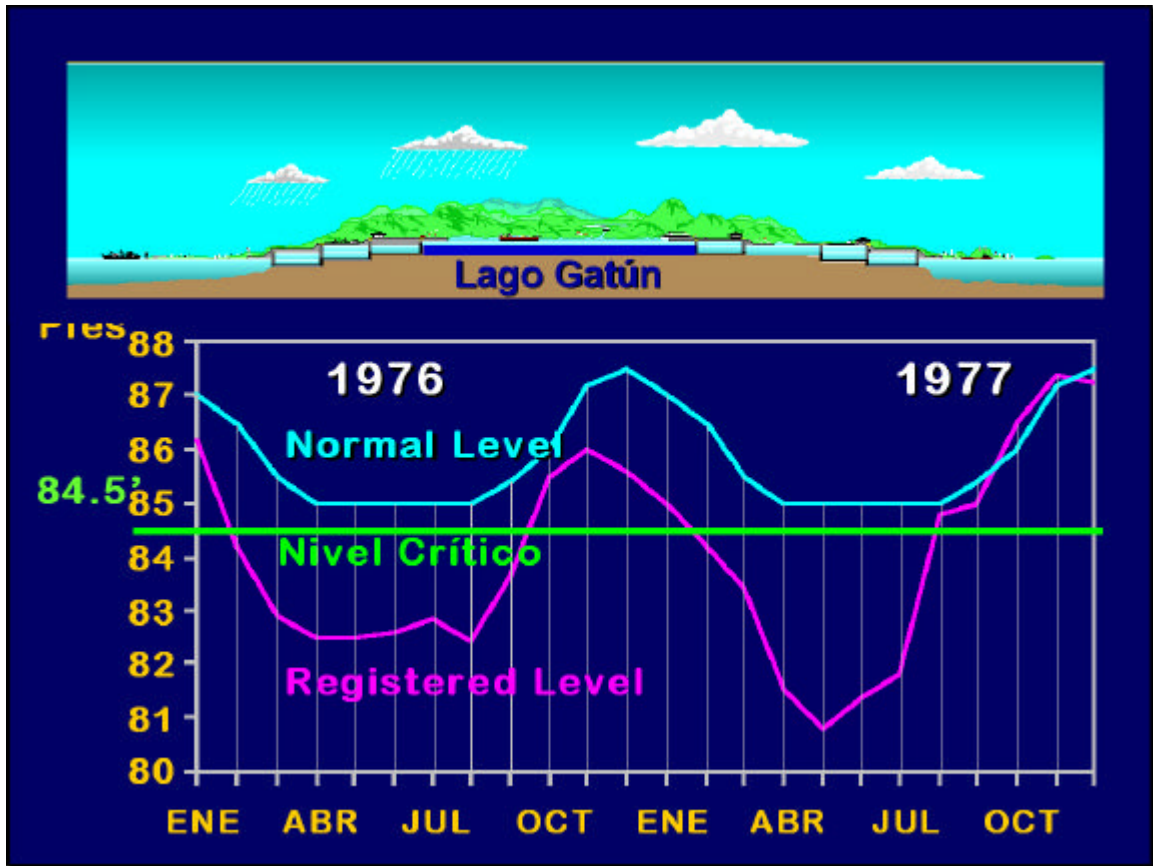
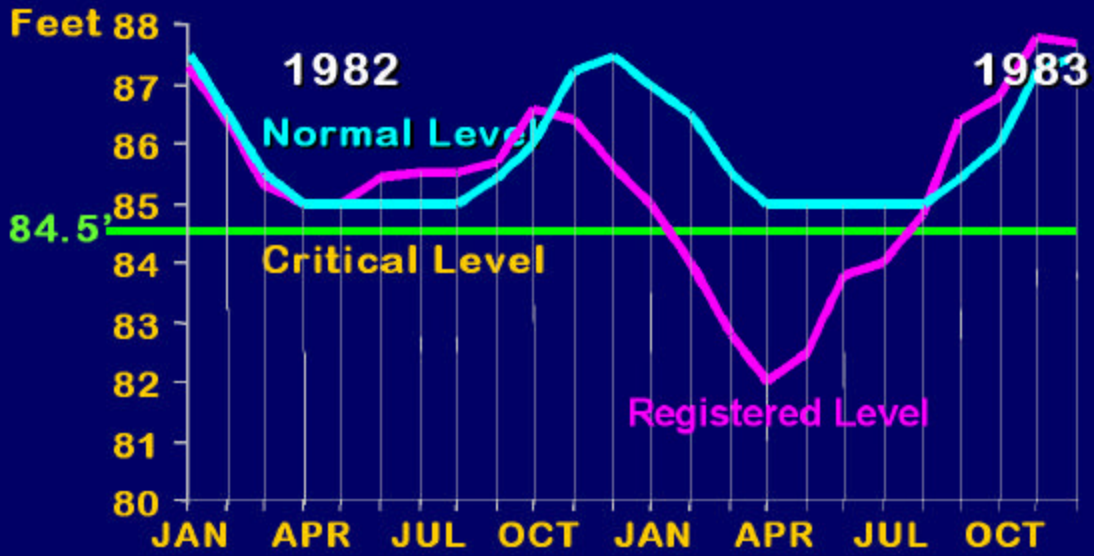
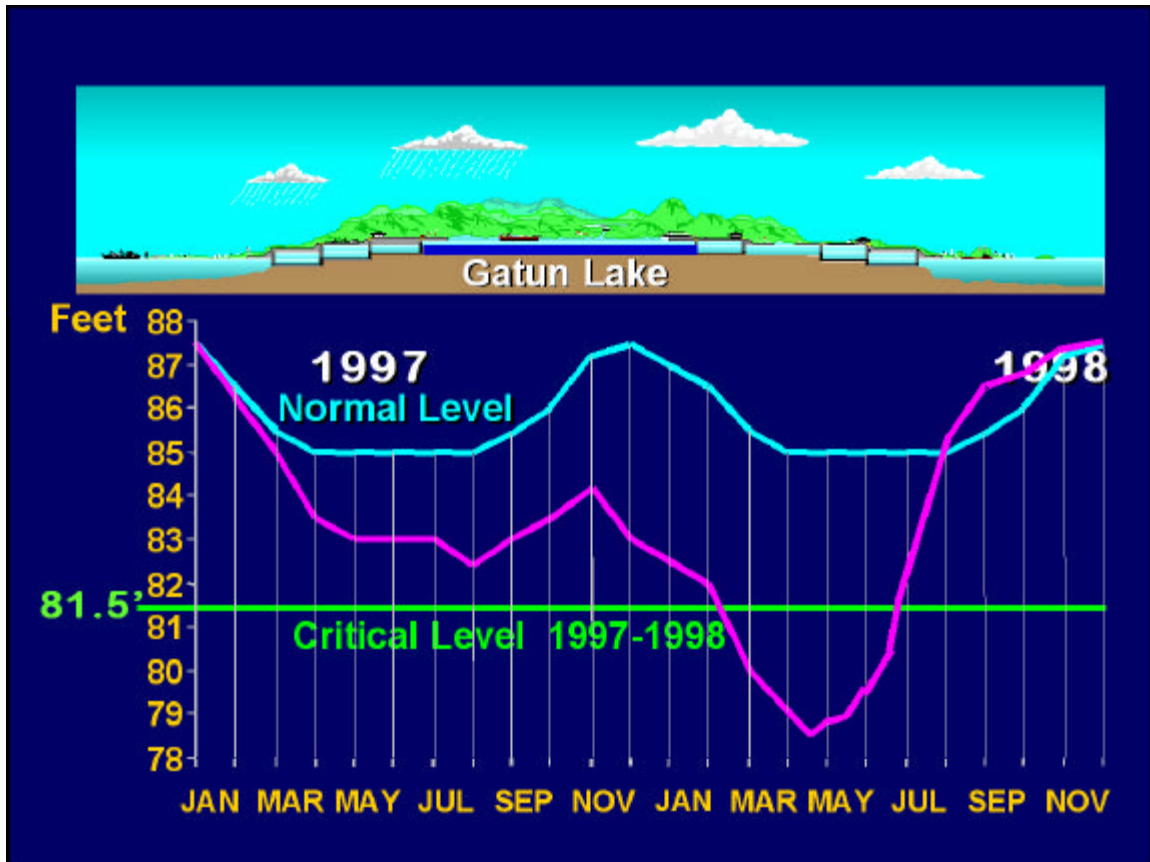


Figure 4 presents the registered levels of Gatun Lake during three of the most severe recent events, 1976-77, 1982-83 and 1997-98.







It is possible to see the clear decrease of the level of the lake. One can also observe how the level gets to be below critical during extended periods. This fact forced navigational draft restrictions in the Canal. After the deepening of the navigable channel by 3 feet in 1983, the critical level was established at 81.5 feet (Panama Canal Spillway, 1996).

These records are clear evidences of the existing relation between precipitation over the Canal watershed and deficit in the Gatun Lake levels during El Niño years.

### **EVALUATION OF THE IMPACTS OF THE 1982-83 EI NIÑO EVENT ON THE PANAMA CANAL OPERATIONS :**

In 1982-83, the El Niño event was of extreme intensity. Before the 1997-98 event, it was considered the most intense and devastating of the 20<sup>th</sup> century. Panama was considerably affected in its precipitation regime, with rains below the average and a dry season that extended long past its normal length. As it is known, the specific engineering design of the Panama Canal, with a system of locks and a navigable lake, makes the water a vital element for its operation. The El Niño event of 1982-83 affected the operation of the Canal. This fact represented the first important impact of an El Niño in the waterway (Barrias, 1997).

The first indication of this happened in November of 1982, when the Gatun Lake did not increase to the

level of 26.75 meters (87.75 feet), as it normally happens during this month. At that time the bottom of the lake was 12.19 meters (40 feet) above sea level. At this time, 25.76 meters (84.5 feet) was the critical level under which draft restrictions were applied. It was at the beginning of the month of February 1983, when this critical level was reached, and the implementation of the first restriction was put in place. It is important to remember that this event was not forecast, and even as the event was developing it was not recognized as the onset of El Niño.

Gatún Lake reached its lowest level by the end of April and, consequently, the draft was restricted to 10.97 meters (36.5 feet). This minimum level remained until mid-May, when the rains returned. The draft restriction was extended until September 1983.

Of the total number of ships that traveled across the Panama Canal, approximately 11 percent were affected by the draft restrictions. There are no available data on the economic impact on shipping companies due to these restrictions. According to the evaluation of the authorities of the Canal, there was no critical impact in the traffic and no extra costs to the Canal resulting from the draft restrictions. One has to remember that at this time the Panama Canal was not a private company, thus the criteria used in defining economic gain and losses were very ambiguous.

With the experience acquired during this event, the Canal Commission decided to deepen the navigable channel of the Canal waterway by 3 feet. They thought that by doing so, if an El Niño event of this magnitude was to occur, it would not be necessary to set navigational draft restrictions, or at least these would not be as significant as those applied in 1983. Of course they did not expect an event of the intensity of 1997-98 El Niño. The 1997-98 El Niño restriction were estimated to have cost 12 millions to the Panama Canal.

## **EL NIÑO FORECAST AND THE FLOW OF INFORMATION TOWARDS AND WITHIN THE CANAL ADMINISTRATION :**

Unlike with the 1982-83 El Niño, the 1997-98 event was forecast some months ahead. This allowed the Panama Canal Commission to take some preventive measures aiming to mitigate any adverse effect that the event could cause on the waterway. The initial prognoses indicated that this El Niño would be of considerable intensity.

The information of the possible presence of an El Niño event was received by the personnel of the Office of Meteorology and Hydrology of the Panama Canal Commission in the month of April, 1997, through the Internet. Around the middle of that year, PCC officials consulted web sites and obtained information indicating that it would be a strong event, The main source for these consultations were the NOAA postings. The information was presented in numerical form, graphical form, tabular form, text and images. The Division of Public Affairs of the Panama Canal Commission also received information on the development of this event through different means, e.g., TV reports, e-mail messages, etc.

The first news disclosed in the written press on the matter of the presence of the warm event occurred in June 1, 1997, through an international news posting coming from Tegucigalpa, Honduras titled " El Niño returns with its pranks ", published in the newspaper La Prensa (Reyes, 1997). The first news on the possible effects of the event in Panama was published in the newspaper El Panama America in June 10, 1997, with the following headline "El Niño phenomenon will cause losses " (in productive areas). Nine days later, a group of experts of the region, participants of the TC3 Network met in Panama City. They included in their agenda the analysis of the state of development of the event. The conclusions at which they arrived with respect to El Niño were disseminated by the local mass media.

The first news that suggested possible effects of the 1997-98 El Niño event on the Canal watershed was published in La Prensa under the title " The El Niño could affect the Canal " on August 17, 1997 (Alvarez, 1997). However, before the news, mentioned above, were published, an article appeared in the local

newspaper La Prensa on January 22, 1997, with the title " El Niño Phenomenon and the Peninsular Rains ". The article was based on an international news posting originated from the Spanish newspaper El Pais. At this time, the 1997-98 El Niño had not shown its face as yet, but the publication was like a precognition of the near future.

Panama Canal Commission employees from several departments organized a working group that met regularly to coordinate efforts before the imminent impacts of El Niño. Participants in these meetings included representatives of the Division of Engineering of the Branch of Meteorology and Hydrography, the Department of Marine Operations, the Department of Engineering Service, and the Division of Public Relations of the Panama Canal Commission. A series of recommendations from these meetings were provided on the actions to be implemented by the different departments of the PCC. The outcome of these meetings was reported to the corresponding authorities who then approved the execution of the recommended actions (PCC-OPA, 1997[a]).

Talks and interviews were given by different PCC employees to keep the Canal authorities, customers and users informed, as well as to professional organizations and the mass media, about the effects of El Niño on the Canal watershed. The Division of Public Affairs was in charge of distributing this information as widely as possible, through official press releases on the situation of the Canal and the measures that were being taken to mitigate the effects of the warm event (PCC-OPA, 1997[b]).

The Department of Marine Operations continuously sent warnings to the ships (users and customers of the Canal) that informed them of the situation of the Canal operations. Special emphasis was given to inform clearly the status of draft restrictions (PCC-OPA, 1997[c]). Twenty-two warnings of navigational restrictions were sent out during 1998 in relation to the ENSO event. As a result of the imposed draft restrictions, the number of ships passing through the Canal decreased 4% during the second trimester of 1998, in relation to the previous year (El Nuevo Herald, July 11, 1998).

## **ASSESSMENT OF SOCIO-ECONOMIC AND POLITICAL IMPACTS OF THE 1997-1998 EL NIÑO ON CANAL OPERATIONS :**

Water is the fundamental element for the operation of the Panama Canal. When the watershed does not receive sufficient rain, the operation of the Canal can be affected. Periods of very low precipitation in the Canal watershed have occurred. Periods of severe droughts, such as the ones that took place during 1982-83 El Niño forced the canal authorities to set draft restriction for ships. In 1983, the maximum allowed navigational draft was 3.5 feet. However, during six months of 1983, the allowed maximum navigational draft value was lowered to 33 feet. Precipitation in the Canal watershed during the 1982-83 event was 14% below normal. With the experience acquired during that event, the authorities of the Panama Canal decided to deepen the navigable channel of the Canal by 3 feet. The project that began in 1984, was completed in 1985 at a cost of \$35 million. After the project was completed, the maximum draft allowed was increased to 39.5 feet.

From the month of May to December 1997, which happen to be the months of expected intense rains in the watershed, the recorded precipitation was significantly below the average. That year, the Canal watershed experienced the worst recorded drought in Panama Canal history. The existing climatic conditions caused a reduction of 25 percent in the run-off toward the tributary lakes of the Canal. In spite of a decrease of 58 percent of the water flow toward Gatún Lake, by the end of September, and in the month of October, the authorities of the Canal officially announced that the operations in the Canal would *not* be affected for the remainder of the year (PCC-OPA, 1997[b]).

The forecasts of the experts in meteorology and hydrography of the Canal Commission were not very encouraging for the first months of the year 1998 (Rodríguez, 1997). Based on the experience from the 1983 event, the draft restrictions were forecast to begin as of February 1998, in view of the possibility that



the levels of the lakes would be unable to recover as the dry season was already approaching (La Prensa, December 6, 1997; Alvarez, 1997).

Knowing what the situation of the Canal watershed would be like, measures were taken to mitigate the effects of the event, and to avoid that negative impacts would affect the customers and users of the Canal, as well as the public in general. The measures taken were as follows (Alvarado, 1998):

- water saving by stopping the generation of hydroelectric power at the Gatun plant, and replacing the lost electric power by the more expensive thermoelectric generation. (The Gatun hydroelectric plant is only used when there is an excess of water in the lake, because it spills the water directly to the sea).
- saving water by using small chambers for ships of suitable sizes,
- saving water by eliminating the hydraulic mechanisms used to help push the ships out of the chambers of the locks, and by using additional towing locomotives,
- saving water by means of ship transit through the locks in tandem (more than one ship per lock),
- saving water by means of crossed water transference between adjacent chambers,
- maintenance of a safe depth in the navigable channel of the Canal through the implementation of nearly continuous dredging.

These measures adopted for the conservation of water were also aimed to diminish to the minimum the adverse effects of the event on customers and users of the Canal. The implementation of these measures had a cost of \$10 million to the Canal, but at the same time they brought savings of water of about 10 to 15 percent. This translated into daily savings of more than 180 million gallons of water.

In addition to these actions, in December 1997, it was decided to carry out a study on the physics of the displacement of the water by the ships in transit to establish a program of navigational draft reduction. This study cost \$200,000.

Another action adopted was to make a complete sounding of the bottom of the Canal section known as Corte Culebra that would guide the dredging of this section. This would help to eliminate all the accumulated sediments and to diminish the draft restrictions. This work cost \$1.5 million.

The adopted measures, together with the continuous monitoring of the important hydrometeorological parameters for the Canal watershed, allowed for a delay in the setting of draft restrictions. Originally, it was thought that draft restrictions would need to be set by the end of February, 1998. But it was not until March 12 (PCC-OPA, 1998[a]), that the Canal authorities issued the first of their 22 warnings announcing draft restrictions because of El Niño. These warnings were issued to the users with an average of 3 weeks in advance to their implementation.

On March 12, 1998, months after the implementation of the measures for water conservation, the first draft restriction was applied (Guitierrez, 1998[a]). This fact was beneficial to the customers who traversed the Canal from the end of February to March 11, enabling them to transport more cargo than would be the case after March 12. The allowed maximum draft in the Panama Canal was decreased to 39 feet, half a foot less than the allowed maximum draft in normal times. Obviously, some customers were affected by these restrictions. A reduction in draft of half a foot, depending on the type of ship, could represent a loss of lifting capacity of up to several hundreds of tons of cargo.

The allowed maximum draft was reduced by a half-foot every time a restriction was set, until it reached a minimum value of 35.5 feet on April 19, 1998 (Bethancourt, 1998). This draft restriction stayed in place until April 28, when the allowed maximum draft was increased with the coming of the rains that began to fall mainly in the Atlantic sector of the watershed. Progressively, as rain began to fall over the Canal watershed, the draft was increased until returning to its normal value of 39.5 feet on July 29, 1998 (PCC-OPA, 1998[b]). Fortunately, some earlier forecasts related to the draft restrictions did not come true, such as the one that predicted that the allowed maximum draft would be reduced to 33.5 feet in May 1998. If this would have happen, it would have further affected the customers and users of the Canal. On August

25, 1998, the Panama Canal Commission reported that the canal lake levels had returned to normal (PCC-OPA, 1998[c]).

During the period of draft restriction some customers of the Panama Canal could decide on alternative routes like the North American coast-to-coast railroad, and the Suez Canal. Some canal economists were afraid that the programmed increase in tolls by the PCC for January 1998 would have a negative impact in the international marine community and affect the volume of traffic through the Panama Canal. This increase had been programmed, before the appearance of the El Niño with the purpose of gathering funds for financing extension works in Corte Culebra.

The interruption of the generation of hydroelectric energy at the Gatun hydroelectric plant to save water had an adverse affect the Panama Canal. The PCC was deprived from receiving between \$5 to 8 million from the sale of this energy (La Prensa, 1998[c]).

In spite of the negative effects of the 1997-98 El Niño, such as the big drought in the Panama Canal watershed, caused by a reduction in precipitation of almost 35 percent, and the investment of about \$12 million that the PCC had to make to mitigate these effects, the income obtained by the Panama Canal Commission, not only fulfilled the expectations that had been projected for that fiscal year (October 1997 to September 1998), but it surpassed them. The income (\$743 million) had an increase of 10.6 percent with respect to the previous year's income (\$663,9 million). This success, according to declarations of the PCC authorities, was possibly due to several factors (Cajar, 1998[b]). One of them, and possibly the most important, was the capacity of the personnel to plan and to implement actions to counteract the critical climatic conditions in the region created by the 1997-98 El Niño. Other factors included the adoption of the new tariffs of tolls in 1997 and 1998, the increase of the traffic of ships of greater width in the Canal, and other services that the Canal offered.

Although the Panama Canal could, through successful management, face one of the hardest contingencies ever experienced, the 1997-98 El Niño is still considered the most intense event of the last 150 years. Various customers and users were affected during the period of four and a half months of draft restrictions. The ships that were mainly affected were those carrying bulk load, the tankers, and container carriers. Between March 12 and May 20, 1998, 2.612 transits occurred, and of these 289 ships (11 percent) had to reduce their drafts to be able to go across the Canal, a low percentage according to the authorities of the Canal. Some of these ships, having to reduce their draft, experienced a loss of lifting capacity of up to a thousand tons for each half foot of draft restricted. These restrictions obviously affected their economic gains. For example, from March 12 to April 16, 1.375 ships passed through the Canal, of these 138 were affected due to draft restrictions by being forced to reduce their cargo by approximately 500,000 metric tons. This has brought the Canal authorities to consider deepening the waterway by a few feet more, as had been done in 1984 (Ruiloba, 1999).

But El Niño was not a negative influence to all sectors related to the shipping industry. The ports at both ends of the Canal (Balboa and Cristobal) actually experienced an increase in revenue, because more cargo moved through the port-highway system (La Prensa, April 12, 1998). As a result of the draft restrictions imposed by the Panama Canal, more ships were forced to leave/pick up and transfer cargo through the Isthmus. Douglas Barr, chief of operations for Hutchinson Ports Ltd. in Balboa, commented to La Prensa that El Niño had affected the Panama Canal, but not their scheduled activities (Guitierrez, 1998[d]). However, this optimism was not shared by the shipping companies. As stated in April 1998 by an Evergreen official stationed in Panama, "ultimately the shipping companies will be the ones to receive 'the blow'", meaning they will be the ones who will have to pay for changes in their operation mode due to El Niño.

## **THE USE OF EL NIÑO INFORMATION IN THE PANAMA CANAL: STRENGTHS AND WEAKNESSES (SUMMARY) :**

The Canal Authority does not have the resources to forecast the El Niño events, and therefore it depends on the information that it acquires from the international institutions that forecast and monitor ENSO events. The different experiences gained during the 1982-83 and 1997-98 El Niño highlights the importance of obtaining early forecasts of these events to guarantee better management of the water resources of the watershed. It is not difficult to imagine what might have happened to the operations of the Panama Canal during the warm event of 1997-98, if in 1984 it had not been decided to deepen further the navigable channel of the Canal of the forecast of 1997-98 event had been delayed.

Newspaper, radio, television and other forms of the press are important channels to disseminate information about climatic events, and also important forces that can either contribute to mitigate the impacts of such events by alerting the general public, or can cause unnecessary unrest, even hysteria, when the intensity of the event is exaggerated. In the case of the 1997-98 El Niño, the media did not influence the decisions or actions undertaken by the former Panama Canal Commission (PCC) with regard to the operation of the waterway. The PCC conducted business based on its experience during the 1982-83 warm ENSO event, and the interpretation of information coming from sources such as the National Oceanic and Atmospheric Administration (NOAA). As a matter of fact, the local press generally based its coverage of the situation referring to the Panama Canal on the press releases issued by the PCC Office of Public Affairs (OPA). This was not the case in relation to other sectors, such as agriculture, where speculation from the part of some media agencies would sometimes run wild.

However, in general the treatment of the 1997-98 EL Niño by the local press was relatively professional (Franceschi, 1998; Guitierrez, 1998[b]; Kovaleski, 1998; Vogel, 1998). The same can be said about the international press with regard to the coverage of the impacts of the last warm ENSO event in Panama as a whole, and in particular with respect to the Panama Canal. The reason for such moderate reporting on the effects of the 1997-98 El Niño in Panama, could be that enough catastrophic footage was coming in from Peru and Ecuador, and later from Honduras (after the passage of hurricane Mitch), that there was no need to exaggerate the situation in other countries in order for the media to have “attractive” headlines.

In summary, as stated by the Panama Canal Administrator, Mr. Alberto Aleman Zubieta, the rapid response of the canal's authorities to the 1997-98 EL Niño demonstrated their capacity to handle major problems (Barnard, 1998). The action plan implemented during in response to this extreme climatic event was based on the interpretation of information coming from adequate sources such as NOAA, enhanced by the input provided by local experts and the expertise gained by the PCC during the 1982-83 warm event. However, the continuous and accelerated changes in land use that are taking place in the canal watershed calls for a permanent monitoring of the basin and a constant verification of the models that simulate the response of the canal system to climate variability. Furthermore, with the approval of the new Law 44 of August 31<sup>st</sup>, 1999, the legal territory the hydrographic watershed was extended to included three other river basins, namely Rio Indio, Caño Sucio and Coclé del Norte, all three located to the west of Gatun lake in the Atlantic region. The annexation of these three river basins to the canal system, together with the proposed structural modifications of the waterway, will also provide new elements to be considered when modeling the potential impacts of future warm/cold ENSO events on the Panama Canal.

In conclusion, research on the impacts of climate variability still needs to be carried out in parallel with the future development of the Panama Canal system.

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