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Some History and Hydrology of the Panama Canal

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I - Introduction

The Hydrologic Engineering Center (HEC) participated in the development of models for evaluating current and future alternatives for sustaining and improving water management of the Panama Canal. This paper presents some history regarding the construction of the Panama Canal and a general overview of the hydrology of the canal watershed.

II - Historical Overview

The United States officially took over the task of canal construction on May 4, 1904. Approximately ten years later, on August 15, 1914, the steamer SS Ancon made the first official canal transit. Much has been written about the events that led up to the United States taking up the gauntlet, after the French attempt which cost dearly in economic and human suffering. The French exerted intense political effort within the US in the hope of recovering some of the financial loss they suffered. Significant conflicts existed between several US political factions regarding where an Atlantic-Pacific canal should be built.

Gaspar Alvarado

Dedicated in memory of

Gaspar Alvarado
March 7, 1939 to July 20, 1999

Hydrologic Engineer
Panama Canal Commission

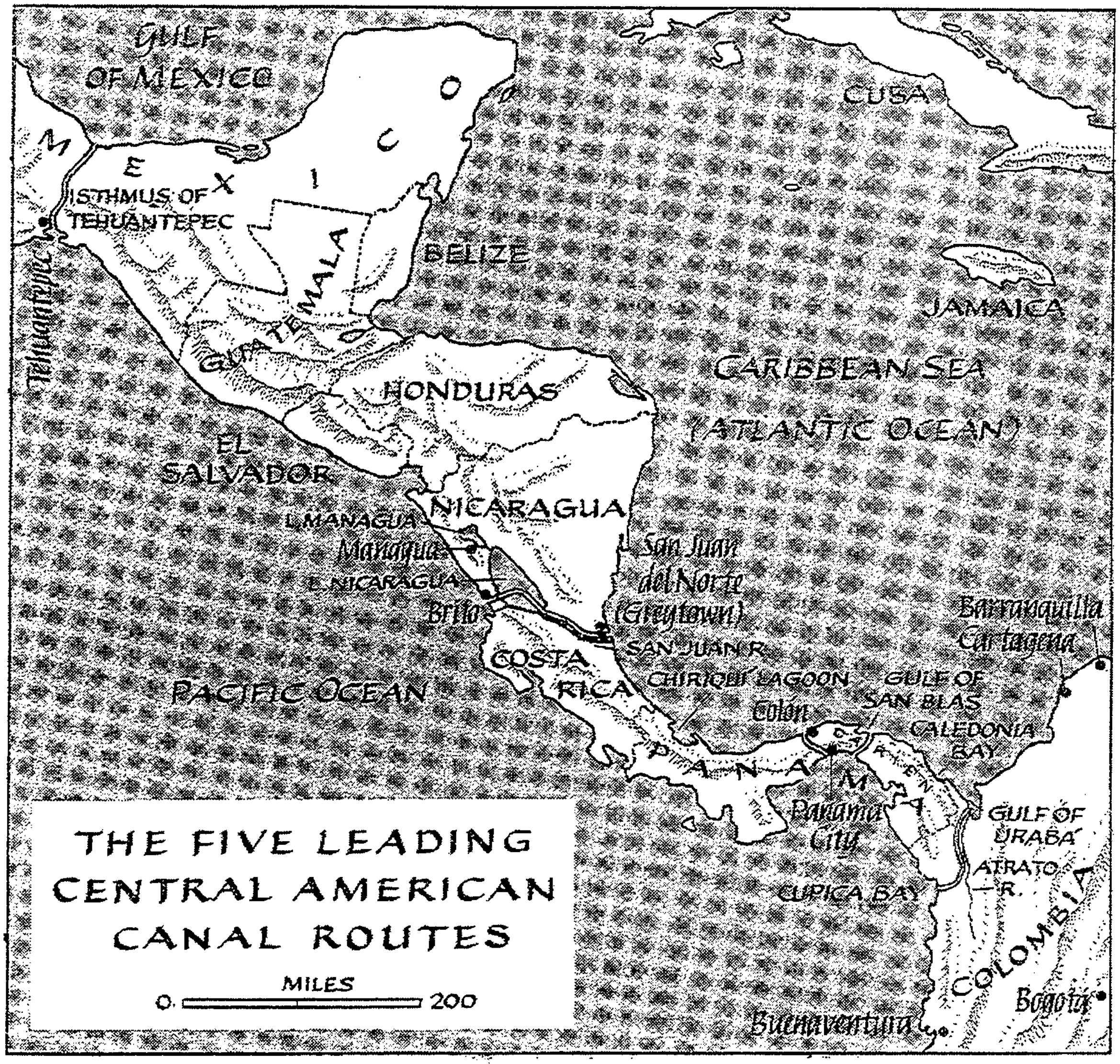

Figure 1 Alternative canal sites. (From Ref. 1)

Figure 1 shows five of the proposed routes that were under consideration. The strongest alternative to the actually constructed route was the one in Nicaragua. Politics at the time played a significant role in these decisions as compared to engineering considerations. There were several interests that sought to influence which of the routes should be chosen, with the French hoping to reduce their financial losses by selling their canal rights in Panama to the US.

Figures 2 and 3 show items that were used by the advocates of the Panama route to counter those favoring the Nicaragua route. The flat arch located in Panama City (shown in Figure 2) was offered as proof that Panama was an area of stable ground conditions. As the photo shows, this flat arch still exists today. The Nicaraguan postage stamp (shown in Figure 3) was sent to each US senator to carry the message that Nicaragua was an area of unstable ground conditions.

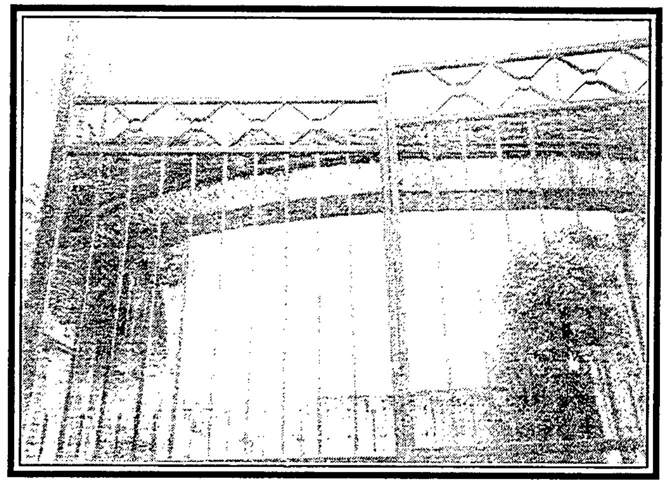

Figure 2 "Flat arch" in Panama City, Nov 1998.

In the time preceding the route decision, Panama was a territory of Columbia. The choice of Panama as a route naturally required negotiation with Columbia. These negotiations did not go well, eventually leading to the local Panama politicians triggering a revolt for their own independence from Columbia. The US stood to benefit greatly by such a change and under the guise of protecting US interests in the Panama Railroad, US Naval vessels appeared on the Atlantic and Pacific coasts of Panama effectively blocking Columbia from dealing with the rebellion. In the end the French interests were payed $40,000,000 for the canal works, the new Panama government was payed $10,000,000 and the US effort commenced. Later, in 1921, Columbia was payed $25,000,000 by the US for the loss of Panama.

Figure 3 Nicaraguan stamp showing a volcano. (From Ref 1)

III - Engineering Considerations

The French had considered several alternative canal designs in their initial efforts. The sea level design had won out based on the successful French built Suez Canal. With greater engineering information to go on, the US abandoned the French design and proceeded with a design based on a large lake at elevation 85 with three locks at the Atlantic (North) side at Gatun and a one and two lock combination on the Pacific (South) side. The sea level design suffered greatly from the larger volume of excavation required and from flooding that would have occurred along the Chagres River. The Chagres River was subject to frequent flooding that would have endangered the canal and impacted navigation traffic. By constructing a dam near the mouth of the Chagres River, the combined effect of reducing excavation and mitigating flood impacts was achieved at the cost of constructing lock structures.

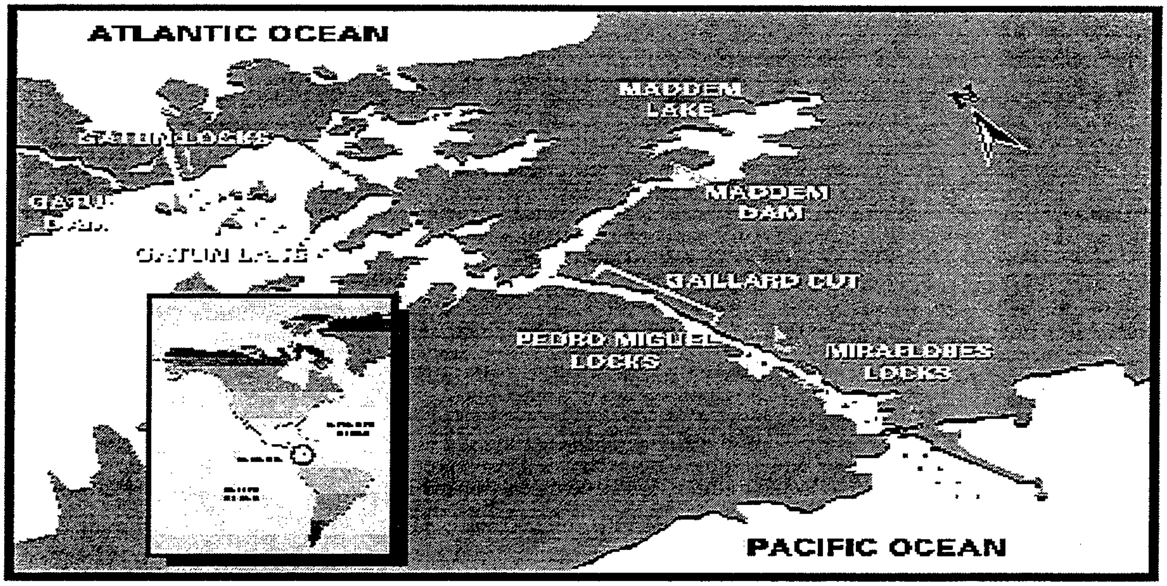

Figure 4 Panama Canal Features, Gatun and Madden Lakes.

Figure 4 shows the location of the lakes and lock structures. Dual lock chambers were constructed at all locations permitting bidirectional transits and allowing lock maintenance to be performed with only reduced traffic capacity. All lock chambers are 1000 feet in length and 110 feet in width. The locks are controlled by a well designed electro-mechanical control system (Figure 5) in place and still functional since 1914. Some of the lock gate systems (Figure 6) have been upgraded with hydraulic components; however, in some locks the same gear mechanisms that were designed in 1914 are currently being used to open and close the lock gates.

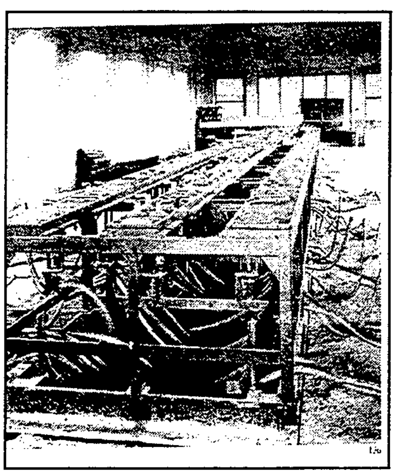

Figure 5 Lock control panel. (From Ref 2)

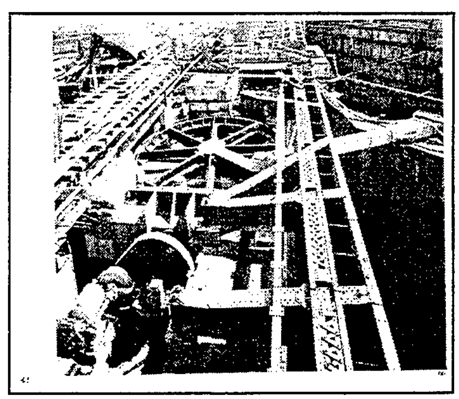

Figure 6 Gear gate mechanism 1914 (From Ref 2)

IV - Hydrology

The Panama Canal watershed is 1289 square miles drained by six rivers. The Chagres is the largest of the rivers and is the source for a major portion of the watershed runoff.

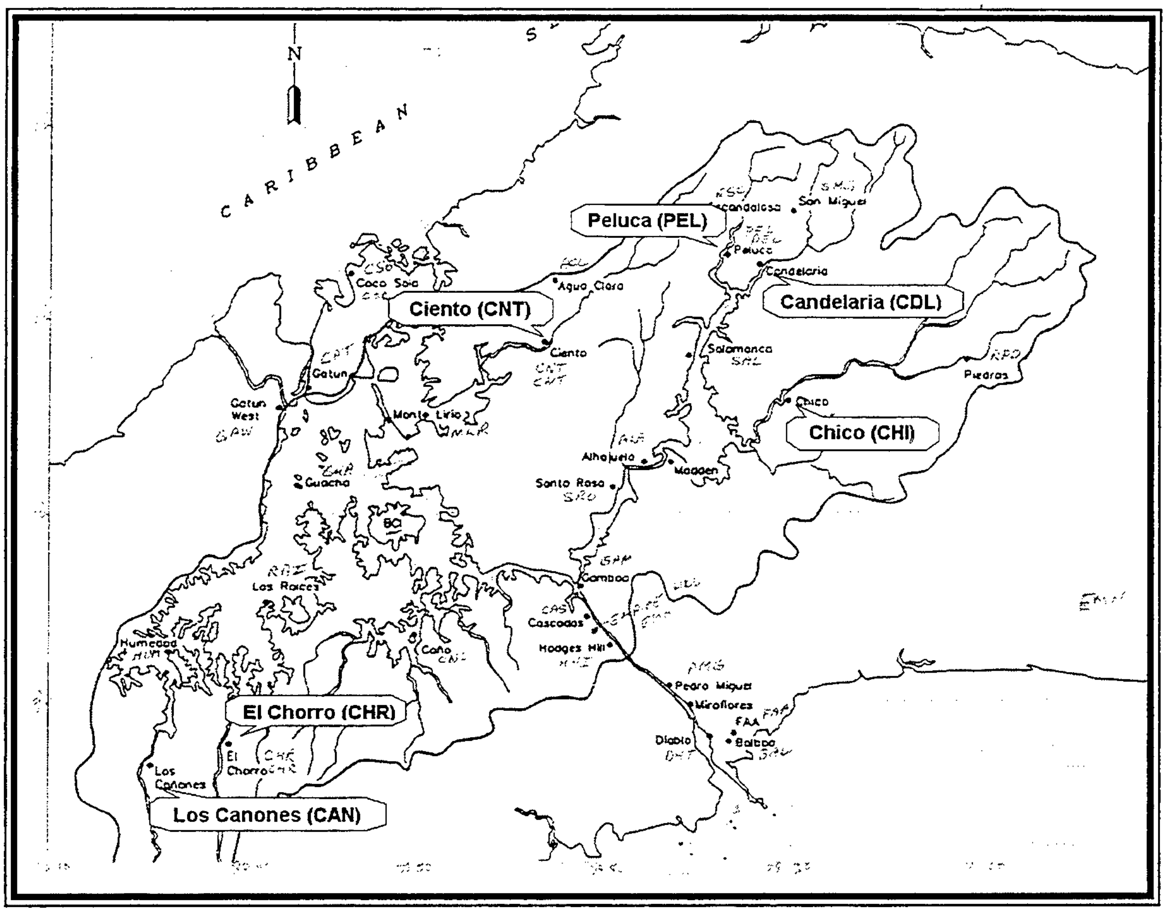

Figure 7 - Map showing stream gage locations.

Figure 7 shows the location of the major stream gages in the basin. Clockwise from the top the Gatun River is gaged at Ciento (CNT), the Boqueron at Peluca (PEL), the Pequeni at Candelaria (CDL), the Chagres at Chico (CHI), the Trinidad at El Chorro (CHR), and the Ciri Grande at Los Canones (CAN). The records at these long term stations provide excellent information for modeling runoff into the system. The Madden dam on the upper Chagres was completed in 1934 to provide water storage, flood control and hydropower. The Madden dam controls 396 square miles of tributary area. About 30 years of data are available for all these gages with longer records being available for some of the gages. Four meteorological stations record wind, humidity, radiation and related parameters.

A network of more than 30 precipitation gages and a weather radar station monitor rainfall events over the area. The locations of the precipitation gages are shown in Figure 8. The predominant storm direction is from the north. On the Atlantic coast, warm moist air from the Caribbean Sea crosses the isthmus moving southward. The mountains (400 to 900 feet high) along the northeast coast of the watershed cause uplift which contributes to the production of about 130 inches of annual precipitation in that area. Thirty miles south (at Balboa on the Pacific coast) the precipitation is about 60 inches, or only half as much.

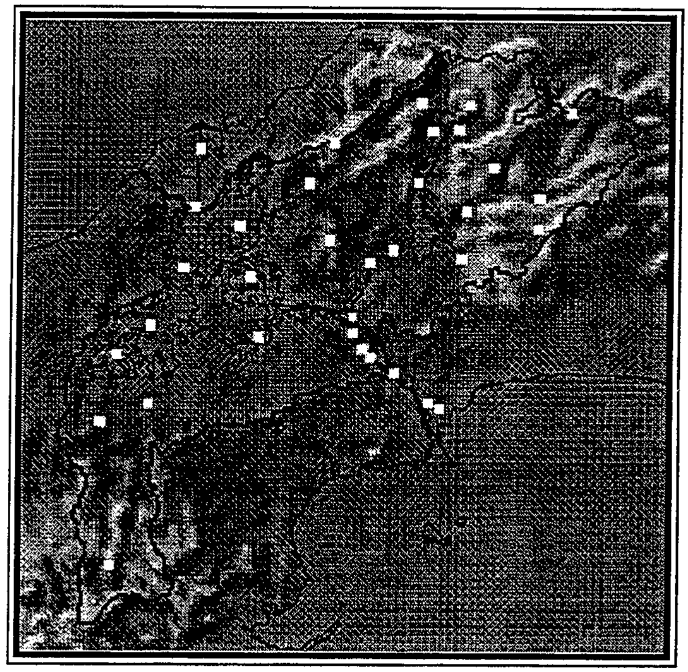

Figure 8 Network of Precipitation gages.

Figure 9 shows the key elements of the water budget in the Canal watershed. Madden Lake receives inflow from its contributing drainage area. Municipal water supply is withdrawn from the Madden Reservoir. All other outflows from Madden contribute to Gatun Lake. Madden attempts to pass all of its releases through its power turbines. Spillway discharges are necessary during high flow periods. The primary use of Gatun water is for lockages on the Atlantic and Pacific coasts. When excess water is present, discharges are made through turbines at Gatun Dam. Flows in excess of turbine capacity are passed over the Gatun spillway. Municipal water supply is also withdrawn from Gatun Lake.

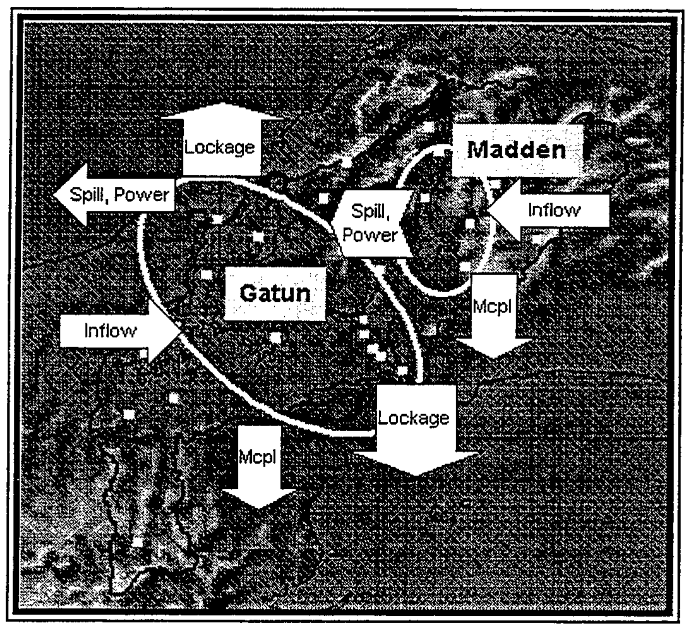

Figure 9 - Water budget for Panama Canal System.

On an annual basis, the Canal watershed receives about 101 inches of precipitation. Approximately 40 inches of this precipitation is lost from the perspective of water budget, going to infiltration, groundwater and plant use. Approximately 6 inches is estimated to evaporate from lake surfaces. Spill during high flows accounts for about 4 inches on an annual basis. Of the remaining 51 inches, 31 inches are used for lockages, 17 inches are used for hydropower, and 3 inches satisfy municipal water supply needs.

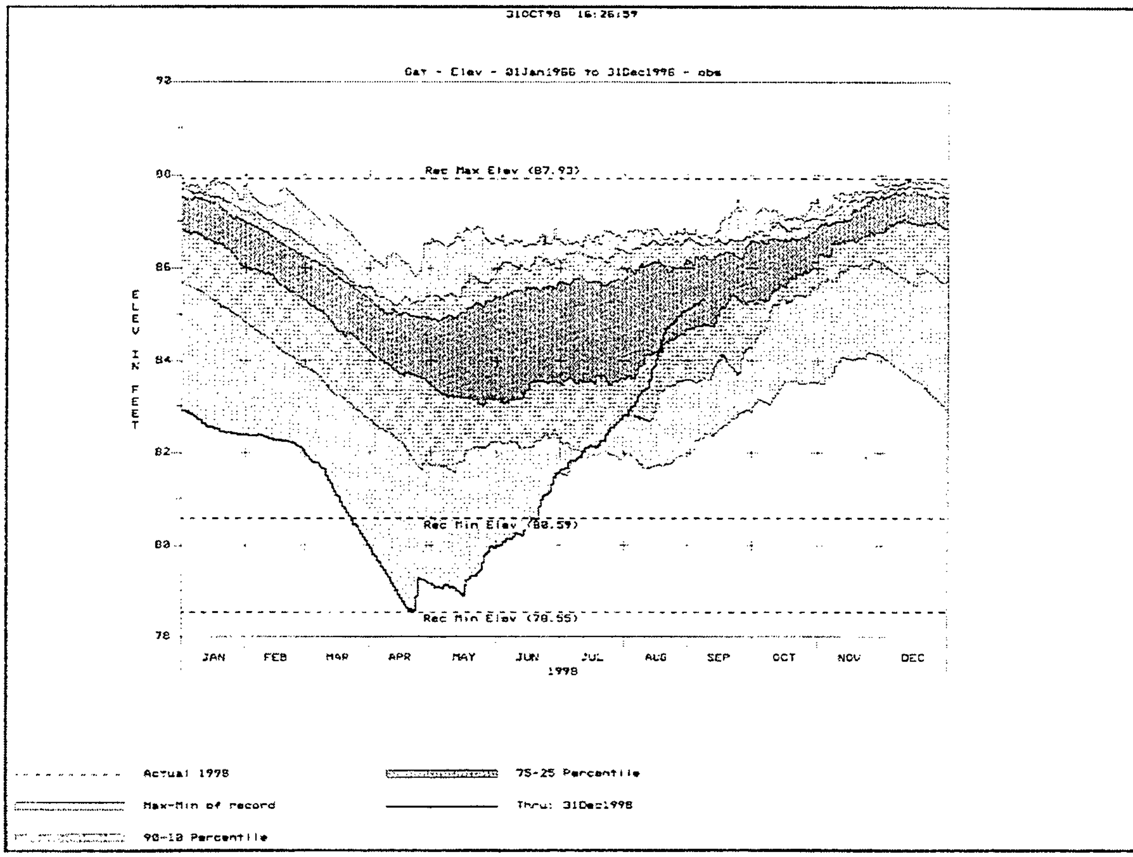

Figure 10 - Percentiles of Water Surface Elevations for Gatun Lake (1966 to 1998).

The nominal water surface elevation of Gatun Lake is 85 feet, with an average elevation of 85.70 feet. The maximum elevation of record is 87.93 feet (shown by the dotted line near the top of Figure 10) occurred in 1993. Of particular interest is the lowest elevation of record. Until 1998, the lowest elevation of record was 80.59 feet. In 1998, the level dropped to 78.55 (shown by the dotted line near the bottom of Figure 10), a full two feet lower than previously experienced since the canal was opened in 1914. Figure 10 shows percentiles of Gatun lake elevation on a daily basis for the period 1966 through 1998. The curves from highest to lowest are: the Maximum value, 90 , 75 , 25 , and 10 percentiles, and the Minimum value. The canal watershed system shows a remarkable resilience in its ability to recover from extreme conditions. The dark curve traces the daily elevations through August 1998, where it returned to the median level (after the record low in April).

V - Reservoir Modeling

In support of Panama Canal Authority (PCA) studies investigating canal capacity, the HEC developed an HEC-5 Reservoir simulation model of the existing canal system. The model included the two reservoirs, Gatun and Madden, reservoir operation rules, and a representation of the system water demands for lockage and municipal water supply. The HEC-5 model also included hydropower generation, spillway discharges, and lake evaporation. The model was verified using the derived lake inflows for the period of January 1980 through July 1998. The model was evaluated as to its ability to represent the behavior of the system under existing conditions. The verified existing condition model was then the basis for evaluating alternative system modifications. As alternatives are proposed, the model can be changed to evaluate the ability of the system to meet increased lockage demands, growth in municipal usage, and hydropower goals. Those alternatives that appear to be feasible can be simulated in detail at a daily operational time interval.

VI - Acknowledgments

In addition to the references cited below, a great deal of information was provided by PCA staff. Significant contributions of basic data, discussion on behavior of the canal system, and operating experience were provided by the following individuals of the PCA Met & Hyd Branch: Sigli Probst (Retired), Carlos Vargas, Jorge Espinosa, Modesto Echevers, Manuel Vilar, Mike Hart, and Maritza Chandeck. Assistance was also furnished by staff of the Canal Capacity Projects Office: Teodolinda Atencio, Jorge de la Guardia, Abelardo Bal, Agustin Arias, and John Gribar.

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At the request of the Panama Canal Commission (now Panama Canal Authority), the Hydrologic Engineering Center participated in the development of a model to simulate the existing operation of the Panama Canal System. This model was developed to be a basis for evaluating alternative water use scenarios. The model reflected the existing two lakes (Gatun Lake and Madden Lake), navigation lockage water demands, municipal water supply, hydropower, and flood spillway flows. This paper describes some of the history related to the construction of the Panama Canal, the lock and lake design that was implemented, and some of the water uses in the basin.

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