The Panama Canal Water Filtration Plants. State of the art of the early 20th century and the early 21th century. Key elements for the Panama Canal Operations

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WATER DISTRIBUTION PACIFIC SECTION

ABSTRACT

The construction of the Panama Canal by the United States of America started in 1904, right after Panama achieved its independence from Colombia and became a Republic on November 3rd 1903. The initial stages demanded the establishment, among other important issues, of a reliable drinking water system for the work force of the Isthmian Canal Commission (ICC) and the population of the adjacent cities of Panama and Colon. By November 1904 there were already 3,500 U.S. citizens hired to start the works for the new Canal.

Before and during the Panama Canal Construction, other sources of water supply were used successfully. The rivers running south toward the Pacific Ocean, Grande and Cocoli, were the sources for water consumption, coping with the demand and quality of water required.

Years later U.S. approved the construction of two Water Treatment Plants; Mount Hope in Colon (1914) and Miraflores Filtration Plant in Panama (1915).

On December 31 1999 the Republic of Panama took over the operation of the Canal and the new Panama Canal Authority (ACP), replaced the U. S. Federal Agency The Panama Canal Commission (PCC). Under the ACP the new Water Treatment Plant “Mendoza” was built in 2010.

Indeed, having a Water Filtration Plant is a privilege that very seldom someone will find in marine facilities such as ports, navigation channels, marinas, ferry structures. But having three; people will be skeptical of this statement.

The Panama Canal is the exception to the rule. These plants provide drinking water for the cities of Panama, Colon, Arraijan, Veracruz, Chorrera; and the Canal employees including Canal operations. And they have been doing it since the beginning of the opening of the Panama Canal.

The water quality has prevailed through time regardless the continues changes on the regulations and keeping the population from water borne diseases such as cholera whose outbreaks hit South America and The Caribbean in different waves during the 19th and 20th century. This Water Filtration Plants are part of the continued operation of this ingenious structure of the engineering known as the Panama Canal.

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A new challenged arrived during the Canal Expansion Program, providing potable water to ACP workers during a nine (9) year–period. This challenge continues with the new Locks and other facilities. These benefits even though intangibles are embedded silently on the operation.

The paper gives a briefing description on the Plants Process and some information related to census, regulations and previous structures.

Human factor remains a critical element to assure the good operation of the three plants, administrative and technical teams work together to make sure potable water complying with regulation requirements is always available for the consumers.

INTRODUCTION

The main purpose of any water filtration plant is produce water that is safe for drinking. This means, water free of chemical and biological organisms that may cause harm to humans to the point of developing an epidemic.

In 1904 when the United States of America initiated the construction of the Panama Canal, the building of some facilities was required to accomplish the task. Sanitary facilities as well as water treatment facilities were critical to keep the workforce free from diseases.

During the works performance a labor force of approximately 45,000 arrived from the Caribbean islands. Panama City population at that time was about 25,000.

The Panama Canal opened to the world on August 15 1914. Since then it has served the world thanks to its effectiveness and efficiency on the operation as well as having a professional well trained, and though very seldom mentioned, “Healthy” labor force.

Before 1914, during the construction period the priority besides building the canal was the safety and health of the Canal workers and their families. Drinking Water was part of the equation for a healthy population.

Despite the continuous changes on regulations and engineering state of the art on Water Works, Panama Canal Filtration Plants cope with these demands enforced by the local laws and engineering technology.

In addition to the objective presented on the abstract, the purpose of this paper is also to:

a. Present the features of two of the three plants belonging to the Panama Canal.
b. Present the consumption and demands required trough time.
c. Market the importance of the Water Filtration Plants as key elements for the health of the work force.
d. Despite the changes of regulations the Plants still cope with the new ones.

MOUNT HOPE FILTRATION PLANT (MHFP) is not part of this paper, however is important to highlight that MHFP was the first Plant built in 1914. Therefore, its influence on the construction and performance of Miraflores Filtration plant is significant since the data acquire in relation to the behavior of each one of the components in MHFP and lessons learned during the construction aided to predict the behavior of MFP, built a year later.

This latter comment represents the milestone on the performance of the plants since there was no existing data or information earlier recorded.

Potable water is also use for the Chilled Water Plant, and Canal operation Fire Fighting Stations.

Now External demand is 95% of the total potable water produced by the Panama Canal. ACP sells sells potable water to the Panamanian Institute of Potable and Sewerage Waters (IDAAN), who is responsible for the distribution system to the final customer.

The water is provided to Panama City, Colon, Albrook, Los Rios , Cardenas, Corozal, Paraiso, Pedro Miguel, Gamboa, Panama Police Academy, Gamboa Penitenciary, The new Resorts, Arraijan , Howard and Chorrera.

DEMOGRAFY AND WATER CONSUMPTIN (GENERAL INFORMATION)

Starting in 1904 until the present time the population and the clients of the Panama Canal Filtration Plants have changed, nevertheless the goal remains the same.

In early years of the Republic of Panama the population in the Capital Panama City was around 50,000 according to Canal Zone Public Works Division. Water consumption was 246 liters (65 gallons) per day per person or equivalent 3,250,000 gallons.

In 1910 Canal workforce was over 50,000 where 6,000 were U.S. citizen. The rest of the workforce came from the West Indies , Europe and other parts of the world. The consumption was 3,500,000 gallons per day. In 1913 increased to 7,500,000 gallons per day and population including Panama and Colon Cities total 100,000 residents.

In 1920 Canal Zone population was 22,000 inhabitants. During this decade the plants provided services for the following clients.

1. Domestic and industrial consumption for the cities of Panama and Colon
2. Domestic and industrial consumption for the communities of the Panama Canal at Cristobal, Mount Hope, Gatun, Paraiso, Pedro Miguel , Balboa, Balboa Heights and Ancon.
3. Domestic and industrial consumption to the military and naval forces posted at the Canal Zone.
4. Potable water production demand covers the three locks along the Panama Canal as well as all Canal Operation Facilities and Administrative offices.
5. To the vessels making up the canal ports.

The total population was approximately 116,000 persons not including the ship crew and tourists.

In 1930 the Canal Zone population including civilians and military personal was estimated to be 22,858. The consumption was 7,700,000 gallons per day. Population in Panama and Colon Provinces were 180,000.

Table 1 shows the census taken from 1911 to 1970. Panama District had a population of 386,000 in 1979. It is important to point out that not all inhabitants were connected to the distribuition system of the Panama Canal.

POPULLATION IN THE PROVINCES OF PANAMA AND COLON 1911-1970		
YEAR	PANAMA	COLON
1911	61855	32092
1920	98035	58250
1930	114103	57161
1940	173328	79119
1950	248337	90144
1960	372393	105416
1970	576645	134280

Table 1: Panama and Colon Provinces population

By 1954 PCC force total 15,000 employees according to the Canal Zone Census.

Census taken from 1979 to 1998 showed that the workforce population varied between 9,000 and 10,000 employees including U.S Citizens, Panamanian Citizens and Third Nationalities. During that period the Plants provided also water to the U.S. Army, U.S. Navy and U.S. Air force Stations in Panama.

By the year 2018 about ten thousand (10,000) employees in the Panama Canal. Panama City communities connected to the old PCC water lines still receive potable water. About 200,000 residents live in those communities. This number does not count the local business. Ancon which is the former Canal Zone area and Military is included in that number. According to the latest census projection the population reaches the 49,000 residents.

Despite human migration the distribution system has not changed much.

PREVIOUS STRUCTURES (EARLY 20th CENTURY)

Among the ICC major concerns was supplying suitable drinking water for domestic and industrial uses during the early years of the construction of the Canal.

The first water supply constructed was the Rio Grande Reservoir south of Culebra (figure 1.) located along the old Panama Railroad tracks. Another reservoir at Culebra Cut (Gaillard Cut) on the other side of the continental divided was used by U.S. Military forces. Its name Camacho (figure 2.)

Americans took advantage of the reservoir built by the French Canal Company. They raised a 5.18 meter-high (17 feet) dam getting a spillway elevation from mean sea level of 71.6 meters (235 feet).

Figure 1: Grande River.

The reservoir effective capacity was 1,193,000,000 liters (315,000,000 gallons**);** Water source was the Grande River flow and Panama tropical rain. To deliver water from Culebra to Ancon a 404.4 mm (16-inch) cast iron (bell and spigot) pipe was installed along the 15.85 km (52,000ft) distance.

A 3,785,000 liter (1,000,000- gallon) capacity concrete reservoir was also built at Ancon. The system was capable to supply water due to gravity up to an elevation of 30.48 meters (100ft).

The pipe distribution was complemented with a 20-inch cast iron pipe. This both pipes were connected together into a 24 inch pipe at the north end of Pedro Miguel locks west lane.

Before 1913, water supply was also provided, when required, by Cocoli Lake. The operation was executed using electric driven pumps. This water shed was temporarily used. The System supplied water at Panama City through filters.

Cocoli was later discontinued due to the flooding and creation of Miraflores Lake.

Figure 2: Camacho reservoir

THE NEW 1915 PROJECT. MIRAFLORES FILTRATION PLANT. (figure 3)

Figure 3: Miraflores Filtration Plant 2018.

Water quality and water demand called for the construction of a new plants. The United States Government approved the construction of Water Filtration Plants within the Canal Zone.

Upon approval, the decision was to build the new plant on the east bank over the hill near northeast of Miraflores Locks. The ground elevation was 35.36 meter (116 feet) above sea level and 18.59 meters (61 feet) above Miraflores Lake level. The plant must have the capability to provide low and high service through a single distribution system. The general specifications included (using original Unit system) :

a. Maximum nominal capacity per acre: 125,000,000 gallons
b. Flow Rate per day: 12,000,000 gallons
c. Maximum capacity at the above rate: 15,000,000 gallons.

Once prepared the scope of work, the budget and the construction approval, Miraflores Water Filtration Plant construction was successfully concluded on March 16 1915 at a cost of One Million Three Hundred Eighty Seven Thousands Four hundred Ninety U. S. Dollars with twenty two cents ($ 1,387,490.22).

The plant previous features included:

a. An aeriation system: When building Gatun Lake, at that time the largest manmade lake in the world, a lot of tropical forest as well as marine plants due to the swap areas were flooded producing hydrogen sulphide gas due to the decomposing vegetable matter. Aeriation eliminated odor as well as amounts of iron coming from Miraflores Lake, Chagres River, and Gaillard Cut, where the intakes were built after the dismantling of Miraflores intake.
b. Head house and Mixing Chambers: To inject Aluminum sulfate to the raw water.
c. Sedimentation Basin: Three sedimentation with the overall capacity of 1,161,290.32 lts (4,500,000 gallons)
d. Filter building: Fourteen (14) filters with a capacity of 2500 gallons per minute each.
e. Clear Well: Built with to two exists where water was transported by gravity
f. Pump Station (PS2 Miraflores)
g. Injection Chamber
h. Effluent controllers
i. Aluminum and hypochlorite mixing apparatus.
j. Hypochlorite of lime dosing apparatus

k. Pump Raw water intake (figure 4.): the first location was chosen to be built at the foothill of the plant over the Miraflores Lake. Nevertheless, due to the heavy concentration of the chlorine in the water the construction was abandoned. ICC decided to build the intake station on the bank of the Chagres Rivers north of Gamboa reach. This Intake station si still in operation. Distance to the Plant was approximately 16 Km (10 miles) (figure 3.). To transporting raw water a 17.3 km (56,762 linear feet), of cast iron pipe was installed.
l. Booster pump station at Balboa (U.S. Pump station 1)

The pipe diameter varied from 24 to 36 inches. The scope consisting on the pipe purchase, installation which included backfilling and excavation work had a cost of Three hundred Fifty Six Thousands Nine hundred Fifteen U.S. Dollars ($ 356,915)

Figure 4: Gamboa Intake Station
At Chagres River

The total cost of wash water tank, aeriation basin, the head house, the sedimentation basin, the filter building, pipe gallery, laboratory, quarters, clear-water basin, and the injection chamber cost was $558,168.

Distribution of the potable water consisted on three parallel lines 6,400 meters (21,000 ft.) in length each. Diameter varied in sizes between 759 mm (30 inches), 506 mm (20 inches) , and 404.8 mm (16 inches).

The three pump stations (Balboa, Miraflores, and Gamboa), cost Two Hundred Thousand Six Six hundred Fifty Four U.S Dollars with Fifty Seven cents ($200,654.57).

A high service reservoir was built at Ancon Hill, located at an elevation of 91.4 meters (300 feet) above sea level approximately with a capacity of 5,677,500 liters (1,500,000 gallons)

Currently there are eleven potable water reservoir tanks located strategically along the system with a maximum capacity of 51.15 ML (13.2 MG)

MFP PLANT PROCESS 1915 to PRESENT

Gamboa Intake

Actually Gamboa is a 4 -pump system where three have a flow rate of 6,400 GPM and one of 4,200 GPM. Since the limitation is the pipe capacity the combine between pumps can give ranges of maximum flow between 15,000 and 20,000 GPM

Paraiso Intake (figure 5)

Paraiso possess five (5) low lift pumps and three (3) booster pumps. The combination between pumps due to pipe capacity range 7,600 to 36,000 GPM

Figure 5: Paraiso Intake Station

Main Plant 1914 to present

Miraflores Filtration Plant is designed to process raw water with the conventional treatment method of the 1900s; the treatment is accomplished with chemical products for coagulation, flocculation, and odor and taste control and for disinfection.

At Miraflores Plant, the infrastructure has a gravity process starting with the aeration basin. Before entering the aeration, basin chlorine is injected.

On the head house and the mixing chambers, aluminum sulfate, and carbon activated are injected as well as polymer. Panama Canal plants are the only that inject fluorine.

The sedimentation basins have a capacity of 4.5 M Gallons. The filters pools are composed with gravel, sand and anthracite. Twenty filters form the filter pool. . The plant was expanded in 1941 incrementing the number of filters and the Clear Well Capacity to 516,129 liters (2 MG)

The clear well expansion in 1940 is designed with five exists. Three run the water by gravity and the other two take the water to two pump stations located in Miraflores. The first pump station was built with the plant. It is called PS2. The second one built in ther 2000s. This latter delivers potable water to west side communities such as Arraijan, Veracruz.

The plant sand filters, due to increase in potable water demand from these plants, were renovated in the late 1970´s, anthracite was incorporated over the sand, the filter layer design was resized and a surface wash water system was installed.

Treatment up to this time remains conventional on most of the stages, aluminum sulfate, liquid chlorine are the primary chemical products; activated carbon is used, fluoride addition is required by the Republic of Panama law, Miraflores uses polymers in different times of the year when process results show that its use is cost effective and efficient in the quality of the water in process.

Reservoirs are part of a distribution system that mostly has pumping stations, pipelines for filling tanks and transferring the water to the city of Panama at points designated as “delivery points” that also serve as the boundary for Canal responsibility which ends at these points.

The outside view of these centennial plants remind the typical architecture from the past, however inside them the new technology has been incorporated by means of monitoring instrument, remote control for pumps and valves, electronic devices an equipment, pressure and level sensors, all interconnected to a Supervisory and Data Acquisition System (SCADA) that provides real time information for water treatment operators.

The plant can stand up to 200 NTU at the raw station and delivered potable water with a NTU less than .35 which is within the Local laws regulations. During the December 2010 heavy rain called the “Purisima”

turbidity at the intake raised to 800 NTU. Despite that extraordinary event the Plant delivered the water within the numbers required. An schematic of the Pacific Distribution System is shown in figure 6

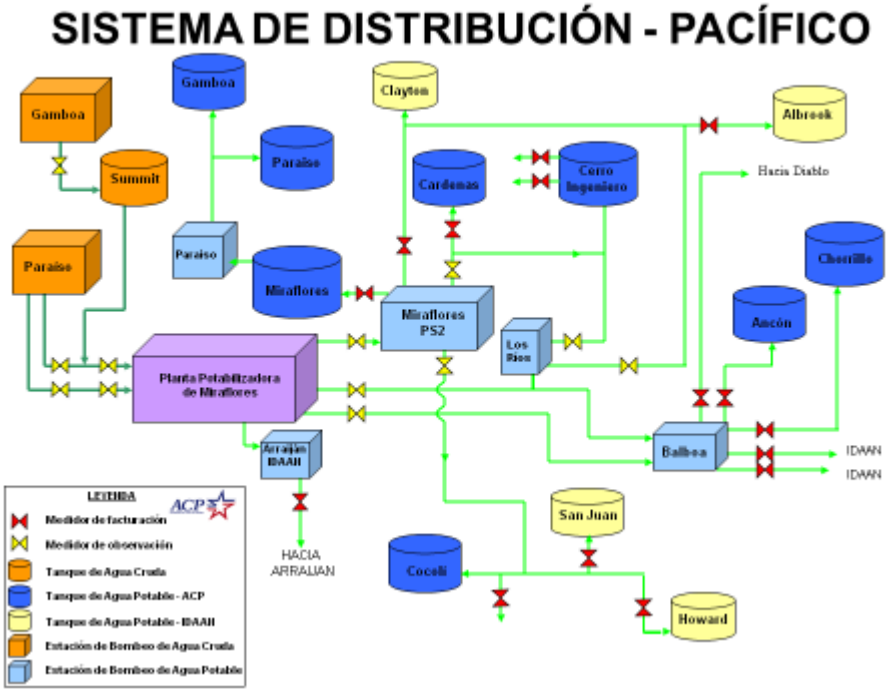

Figure 6: Pacific water distribution schematic

MENDOZA FILTRATION PLANT (MEFP) (21st century PROJECT)

MEFP, designed and built by Biwater International Limited, began operation in 2010, implementing the dissolved air flotation technology for the treatment of the Gatun lake water. Intake (figure 8) is located at La Represa town at a distance of 10km from the plant. The Plant has a capacity of 159 MLD (42 MGD) equivalent to 6624.47 cubic meters/hour for raw water. The potable water maximum production is 155 MLD (40 MGD) equivalent to 6,309 cubic meters/hour. Water flows into the rapid mixing basin where the dissolved air flotation process begins within a concrete structure that includes the areas for chemical dosification, flocculation, filtration, potable water, filter backwash, water settling and sludge drying. Each compart dimension for the flocculation basin is 8m x 5 m with an average water depth of 4m. The volume for each water basin is 160 cubic meters.

MEFP possess five rapid mixing tanks, each with 1,329.92 m3/hour (5,408 GPM), five (5) flocculation lanes and twelve (12) dissolved air flotation (DAF) tanks .Figure 7 represents the schematic of water treatment process at Mendoza. Table 2. Shows the flow rate water treatment at MEFP.

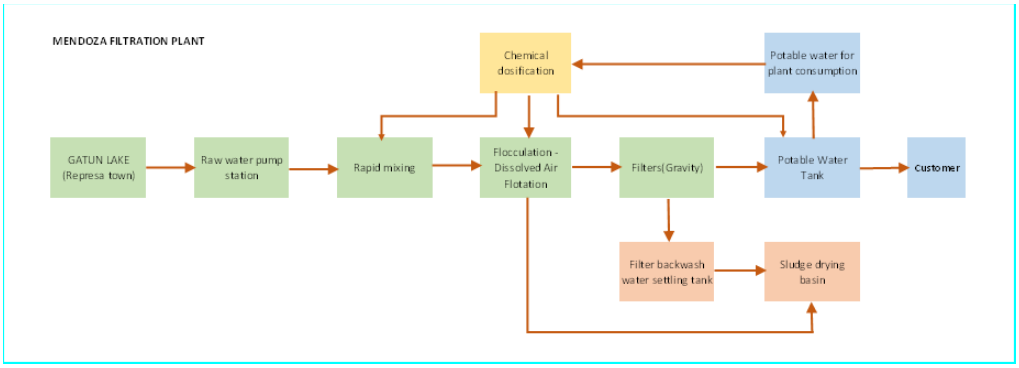

Figure 7: Mendoza Water Plant Treatment Process

FLOW RATE FOR WATER TREATMENT AT MENDOZA					
	Max	normal	MAX	MAX	MAX
DESCRIPTION	c.m./hr	cu.m/hr	GPH	GPM	GPD
Raw Water to Plant	6624	6624	1,747,757.26	29,129.29	41,946,174.14
To Inject Alminum Sufate	1.7	0.8	448.55	7.48	10,765.17
Cl precolation	23.2	23.2	6,121.37	102.02	146,912.93
Carbon	0.126	0.038	33.25	0.55	797.89
Sludge Removal	93.8	40.6	24,749.34	412.49	593,984.17
Entering the filters	6624	7286	1,747,757.26	29,129.29	41,946,174.14
Filter wash water	169.1	169.1	44,617.41	743.62	1,070,817.94
Filter water toward the tank	6386.4	6438.9	1,685,065.96	28,084.43	40,441,583.11

Table 2: Mendoza Water Treatment Flow Rate.

Figure 8: Mendoza Filtration Plant intake at Gatun Lake

GENERAL INFORMATION ABOUUT THE LAWS AND REGULATIONS THAT REQUIRE COMPLIACE BY PANAMA CANAL WATER FILTRATION PLANTS

In 1914 some limited drinking water standards were implemented in U.S. cities

In the 1940s federal drinking water standards were widely applied. In 1941 , the U.S. Department of The Treasury promulgated the country's first drinking water bacteriological standard, a maximum level of 2 coliforms per 100 mL.

Federal regulations and standards for water treatment in a more wide-ranging way were implemented in the 1970s.

In 1972, the Clean Water Act passed through Congress and became law , requiring industrial plants to proactively improve their waste procedures in order to limit the effect of contaminants on freshwater sources.

In 1974, the Safe Drinking Water Act was adopted by all 50 U.S. states for the regulation of public water systems. It identified contaminants that must be closely monitored. This reaction was due to the finding of organic chemicals on drinking water suspected of being carcinogens. Since then, the government, the public health community, and water utilities throughout USA have worked together to safeguard the nation's drinking water supplies and to ensure that law protects public health in the best possible ways.

After year 2000 MFP and Mendoza Plant (2010) had to comply with Panama Ministerio de Salud (MINSA) (“Health Ministry”) and the Autoridad de Servicios Publicos (ASEP) (“Public Services Authority”) .

Mendoza Filtration Plant was design using the World Health Organization which require

CONCLUSIONS

Panama Canal Water Filtration Plants have proven their effectiveness on providing drinking water through 100 years to different stake holders starting with the builders of the Panama Canal, The Panama Residents, Military personnel, tourists and labor forces**.** This is done despite political and administrative changes.

Therefore Miraflores Filtration Plant methodology for treating water has proven to be effective during these periods. This has contributed in addition to other sanitary programs to maintain the country and the Canal Operations from waterborne diseases that may cause epidemics

Waterborne diseases have been controlled from the beginning of the century due to the awareness of providing suitable drinking water to the population of Panama City and Colon and the workforce of the Panama Canal. This event has contributed silently the continued operation of the Canal and its service to the world without facing outbreaks that had occurred in the world.

The above if a great triumph taking in consideration that many of the epidemics or outbreaks have had their origin due to the maritime industry since they were transported by the ships.

Since the Plants were part of the Panama Canal Commission (Federal Agency of the U.S. government) they complied with those regulations.

Miraflores filtration Plant still complies with the 21st century regulations and produce drinking water for an increased population as well as Canal operations.

Mendoza has supported the development of the west bank communities where Canal employees live with their families.

The water quality has mitigate the outbreak of waterborne diseases.

Water treatment process has helped to shape the development of this country. First the construction of the Panama canal, then the operation and demand within the cities, and nowadays the importance during the Panama expansion program. These milestones have been well reported through time. However, without making headlines the water treatment Plants and processes have been silently contribute to the success of these events.

For over more than a century, safe and good quality water for human consumption has been provided continuously to the canal operating areas, the communities alongside de Canal and to Panama a Colon Cities .

The state of the art design can be improved and challenge any other new design.

Water treatment plant basic facilities have not changed much. The process to achieve the quality of the water has been more refined.

Water treatment process still on the move and the latest state of the art technology is far from being discover.

Mendoza has complemented the water supply to the communities west of the Canal, increasing the probability of having healthy population.

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