

## INFLUENCE OF GREAT HYDRAULIC WORKS UPON NATURE AND MANKIND

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**Rezumat.** *Marile uvraje hidraulice reprezintă modificări importante ale mediului înconjurător și influențează atât oamenii (în timpul construcției și al exploatării) cât și mediul natural. Lucrarea de față compară influențele a două asemenea uvraje Canalul Suez și Canalul Panama. Ambele lucrări sunt relative recente, au același scop (favorizarea comerțului mondial pe direcția Est-West) și au fost inițiate de Ferdinand Lesseps. Posibilitatea execuțiilor a fost examinată cu mult timp înainte de începerea lucrărilor. Ambele uvraje sunt importante surse de venituri și au creat lungi dispute între marile puteri. Creșterea prognozată a nivelului oceanic planetar afectează diferit cele două construcții.*

**Abstract.** *The great hydraulic works represent heavy environmental modifications and influence both humans (during the construction and the utilization) and nature. The present paper compares these influences for two such works the Suez Canal and the Panama Canal. Both are relatively recent, have the same purpose (the increase of the East-West trade) and were initiated by Ferdinand de Lesseps. The possibility of realization was analyzed long time before the beginning of the work. Both works are sources of huge incomes and created endless disputes between the great powers. The forecast level increase of the planetary ocean will affect differently these works.*

**Keywords:** Suez Canal, Panama Canal, hydraulic works, history of Suez and Panama canals

### 1. Introduction

The great hydraulic works represent heavy environmental modifications and influence both the humans (during the construction and the utilization) and the neighboring ecosystems. The present paper compares these influences for two very important hydraulic works the Suez Canal and the Panama Canal. For the Suez Canal there are archeological proves regarding the accomplishment of such a waterway during the 12<sup>th</sup> dynasty of Ancient Egypt. For realizing a waterway through the Panama isthmus, the first proposal was made by Charles V, head of Holy Roman Empire and king of Spain [1]. Since opening, these two canals became keys ways for international maritime trade in the east-west direction. Both are exceptional achievements and a source of great revenues. In the past, the incomes created acute conflicts between the great powers. The realization of the canals required hard work and was a tremendous tragedy for local and foreign workers (about 220,000 deceases for Panama and several thousands for Suez). Sea level rise, as result of global warming, will affect differently this two works.

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## 2. General data

**Suez Canal.** The modern ship canal Suez has a length of about 166 km and connects the Red Sea with the Mediterranean Sea (from Suez until Port Said). It provides the shortest maritime route between Europe and the Indian and Pacific Ocean. Built at the initiative of Ferdinand de Lesseps, it was finished in 1869. In present, it is one of the frequently used shipping lanes (in 2008, through the canal passed 21,415 vessels). The Suez Canal is an open cut, without locks, passing through three shallow, water filled depressions: Lake Manzala, Lake Timsah and the Bitter Lakes (Great and Little). The maximum allowed vessel dimensions are presented in Table 1. The recommended values may vary with the draft (for example for a draft under 12.2 m the maximum allowed beam is 77.5 m).

**Panama Canal.** The 77 km long ship canal joins the Atlantic Ocean with the Pacific. Annual traffic constantly rises, reaching 14,702 vessels in 2008. Replacing the long way via Cape Horn, the canal has an enormous impact upon the east-west trade. The distance from New York to San Francisco via the canal is only 9,500 km, instead of 22,500 around Cape Horn. Being more complex than Suez, the Panama Canal comprises the following parts, considered for a route from the Atlantic Ocean (Caribbean Sea) until the Pacific Ocean (Gulf of Panama):

- A 3.2 km long excavated channel begins the route from Limon Bay;
- The three stages Gatun locks (total lift/drop 26 m) is the first master piece of the work;
- The Gatun Lake (a passage 24.2 km long); the artificial lake was realized with the help of two gravity spillway dams, near the Caribbean Sea and Pedro Miguel lock); the Gatun gravity dam is the second master piece of the work;
- The Chagres River (8.5 km long);
- The Madden dam (constructed only in 1935 across the superior sector of the Chagres River) and the resulted Alajuela Lake, acting as water storage;
- The Gaillard (Culebra) cut (12.6 km long); the Culebra Cut is the third but also the most important and difficult masterpiece;
- The single stage Pedro Miguel locks (total lift/drop 9.5 m);
- The artificial Miraflores Lake (1.7 km);
- The Miraflores two stage locks (total lift/drop 16.5 m, at mid tide);
- A 13.2 km long excavated channel ends the route near Panama town.

Table 1 gives a comparison of vessels general data for passing through the waterway. The length, beam, draft and air draft are the maximum allowable values for the ships (the so-called Suezmax and Panamax values).

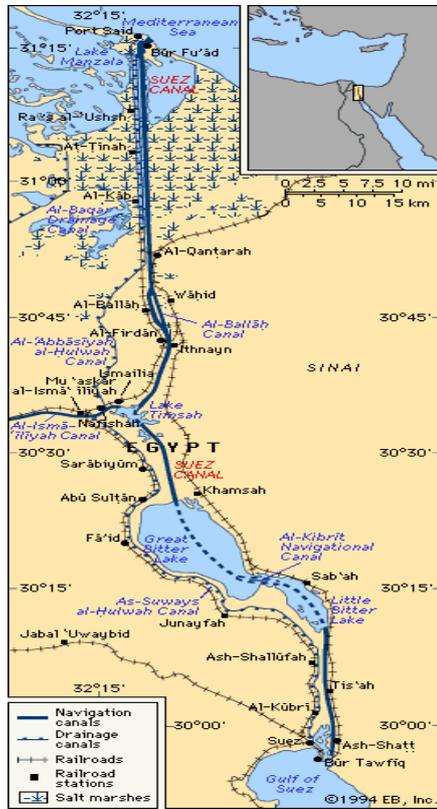


Fig. 1. Suez Canal [2].

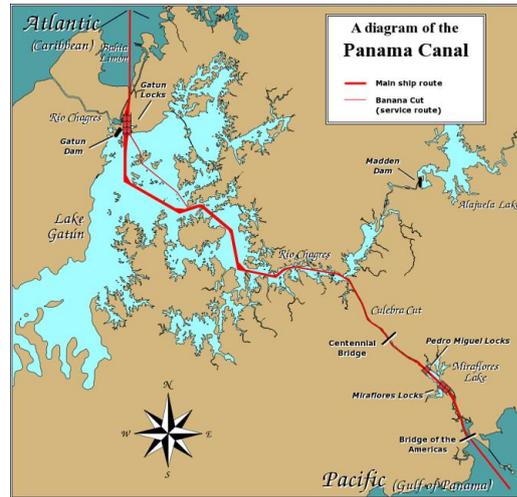


Fig. 2. Panama Canal [3].

Table 1. Ships general data allow passing through Suez and Panama [2, 3]

	<i>Suez</i>	<i>Panama</i>	<i>Suez 2010</i>	<i>Panama 2014</i>
Length	-	320.04 m	-	426.72 m
Beam	46 m	33.53 m	46 m	54.86 m
Draft	18.9	12.50 m	22.0 m	18.29m
Air draft	68*	57.91** m	68 m	57.91
Passage time	11-16 h	9 h	-	-
Passages in 2008	21,415	17,702	-	-

\* imposed by Suez Canal bridge

\*\* imposed by Americas bridge at Balboa

### 3. History

**Suez.** In the ancient Egyptian civilization, commerce was a key factor. Therefore, a waterway between Nile and Red Sea was of utmost importance because it avoids transportation of voluminous merchandise from the south of Red Sea through the desert, by caravans, until the towns of Thebe or Memphis. It is believed, that the first such ancient canal, was constructed under the auspices of either Senusret II or Ramesses II [4]. We strongly believe that Senusret II the fourth pharaoh of the

Twelfth Dynasty built this canal (1897-1878 BC). The most important argument is the mission to the land of Punt (probably the present Somalia) sent by Hatshepsut the fifth pharaoh of the eighteenth dynasty (1508-1458), so one hundred and fifty years before Ramesses (1303-1213 BC). When the five ships came back, through other merchandise, they carry thirty-one live frankincense trees, the roots of which were carefully kept in baskets during the voyage (see the relief at Deir el-Bahri) [5]. Even if we have insufficient information about Senusret II, it is known that he begun intensive irrigation works in the Faiyom region. In this time, the Suez Gulf probably extended through the actual Bitter Lakes, until the Lake Timsah and the Nile had a branch until the lake Wadi Tumilat. Therefore, having small lengths, the achievement of the canal was possible. The canal was exposed to multiple adversities especially choking both by Nile slit and the sand carried out by desert winds. Therefore, rebuilding the canal was imperative. According to Herodotus, at 600 BC, the pharaoh Necho II began the excavation of a canal through Wadi-Tumilat, from the Nile Delta until the Red Sea. Conquering Egypt, Darius I of Persia finalized Necho's project. Because the Red Sea shore migrated to south, it left Bitter Lakes with too shallow water. Therefore, a canal from Lake Timsah until the south of Bitter Lakes must be dug out. French cartographers discovered the remnants of this canal in the second half of the 19th century. Ptolemy II Philadelphus again reopened the canal in 270 or 269 BC. In Arsinoe (ancient harbor on the Red Sea), Ptolemy constructed a navigable lock, with sluices. Until now, this is the unique Suez Canal with lock. After two hundred years, Cleopatra seems to have no waterway passage, because the Pelusiac branch of the Nile River was choked with silt. When Romans conquered Egypt, they became aware of the canal benefits, so emperor Trajan built a new canal till the port of Clysma (in our days Suez) situated a little west of Arsinoe. After Gibbon, annually one hundred and twenty vessels sailed to bring in Egypt silk, precious stones, and aromatics from western India. The present Suez Canal was built as a result of the activity of the French diplomat Ferdinand de Lesseps.

**Panama.** The history of finding a water way across the Isthmus of Panama begin with Columbus who searched the Crocodile River (actually Rio Chagres) in 1503 with the hope to find a secret way to "Cathay and Cipangu". Only in 1530, the non-existence of such a hidden passage becomes recognized. Consequently, the king of Spain Charles V, directed the Governor of Costa Firme district (the territory of present Panama) to survey the Rio Chagres valley in order to find possibilities of realizing a canal to ease the route from Spain to Peru. Alessandro Malaspina, during an expedition between 1788 and 1793 demonstrated such a possibility and realized plans for the canal construction. In 1698 begin the works for realizing a terrestrial route in the Panama Isthmus. Because of difficult work conditions, the initiative was abandoned two years later [1]. In May 1850, a United State Company began the construction of a railroad through the Panama Isthmus. Very quickly, the difficulty of the project became apparent. Much of the route was through jungle

swamps, deluges of rain poured almost half the year, the heat was stifling and mosquitoes were everywhere. The rainy days attain yearly 141 in Panama City, 196 in Colon and 246 in Bohio. It is estimated that from 5,000 to 10,000 people may have died to realize the railroad, especially because of cholera, malaria and yellow fever. In January 1855 the 76 km long railroad was ended.

The success of the Suez Canal (1869) enhanced the idea of an all-water route between the Atlantic and the Pacific. A French company, under the remote leadership of Ferdinand de Lesseps, began the construction of a canal through the Columbia province of Panama on January 1, 1880.

#### **4. Political, Social, Financial and Technical Problems of Construction**

**Suez.** In 1854 and 1856, Lesseps obtained from his friend Said Pasha (viceroy of Egypt) the concession to construct a canal between the Mediterranean and the Red Sea. Because the waterway passes through desert, no problems occurred with the land acquisition. The Suez Canal Company (Compagnie Universelle du canal Maritime de Suez) was to operate the canal for 99 years from its opening. The work started on the shore of the future Port Said on 25 April 1859 and the canal opened to shipping on 17 November 1869. At the beginning, the Company used forced labor of Egyptian workers. Some sources estimate that over 30,000 people work at any given time at the project and that thousands of laborers died especially because of the drinking water quality and yellow fever. The British Government opposed the project from the beginning to its completion. Officially, it disapproved the forced work but none officially sends Bedouins to start revolt among workers. Finally, the viceroy of Egypt condemned the forced labor and the Company must change this recruiting method. Initially, the international opinion was skeptical of the canal benefits so, besides France other countries detain insignificant number of Company shares. After opened to shipping, the Suez Canal had a benefic effect on world trade. The external debts of Ismail Pasha (successor of Said Pasha) forced him to sell his country shares to England, so UK becomes an important shareholder. Later on, the 1888 Convention of Constantinople declares the Canal a neutral zone under the protection of the British. The Anglo-Egyptian Treaty of 1936 confirmed this situation (so, UK who opposed the canal construction became master of the realized work). In 1951, Egypt repudiated the treaty and in 1956, Gamal Nasser (president of Egypt) nationalized the canal and transferred it to the Suez Canal Authority. This provoked the Suez crisis during which UK, France and Israel planned to invade Egypt. To stop spreading the war, the Canadian foreign minister Lester Pearson proposed the creation of the first United Nation peacekeeping force to ensure access to the canal for all nations (proposal accepted in 4 November 1956). In June 1967, Israeli decided to attack Egypt and occupy the Sinai Peninsula. After war, Egypt closed the canal until 5 June 1975 (before, in 1974 USA initiates an operation to clear the Suez Canal from mines)[4].

**Panama.** The success of Suez Canal stimulates Lesseps to begin also the Panama Canal, following the Suez model. Four important obstacles oppose the French project:

*The diseases.* The French managers learned nothing from the disastrous sanitary conditions (malaria and yellow fever) during the construction of Panama Railroad. During 1881 and 1888, period of the French construction, it was estimated that 22,000 workers died. It is interesting to point out some facts. Against malaria, from the 17<sup>th</sup> century was already in use the bark of the cinchona tree. In 1820 two French chemists Pierre Peletier and Joseph Caventon extracted quinine. In November 1880 another French physician Charles Laveran (Nobel Prize 1902) discovered that malaria is caused by a eukaryotic protist of the genus Plasmodium.

*The Culebra Mountains.* The French do not found a technical reasonable way to go with the canal over the Culebra Mountains. The first idea was to realize a ship tunnel but this solution was never seriously envisaged. Cutting the mountains till the sea level was adopted, which means a lot of painful work and the danger to produce slides and breaks because the extremely high walls.

*The Charges river flood.* The Panama isthmus is subjected to heavy tropical rains and consequently the Chagres River is able to rise over forty feet in twenty–four hours. To assure a constant level of the navigable canal, the Chagres must be deviate to the sea through a supplementary canal.

*The corruption.* A great mistake was that the French failed to obtain a canal zone in which to have full power of administration. Building the canal on Colombian territory required sometimes a huge price for the terrain (it is a known case when they must pay a thousand times the real sum; the USA contributed importantly to this situation with the Monroe doctrine). The high salaries paid to the manageress and directories and the elegant mansions erected for their accommodation was a waste of financial resources. In 1888 when the Company went into bankruptcy, the cost of the canal, completed in a proportion of 2/5, was nearly £80,000,000. It was said that 1/3 of the money were spent on the canal, 1/3 wasted and 1/3 stolen [1].

To recover some Company money, the chief of French Canal Syndicate, Philippe Bunau-Varilla hired in 1898 William Nelson to lobby the US Congress to build a canal across Panama and not Nicaragua, such as was proposed. With the lobby successful, on June 19, 1902 the US senators voted the Panama route. Soon after, the High-Herran Treaty was signed, US being authorized to construct a canal and benefit a 99-year lease from Colombia, on the land occupied by the proposed canal. The Panama Congress rejected the treaty in August 1903. A Panamanian patriot José Arango, senator in the Colombian Congress, conceived the idea that Panama must declare its independence and after, make her own treaty with US. The fight for independence of the province had a long history and so, quickly a conspiracy

Junta was formed. Contacting Bunau–Varilla they obtain promises of substantial help but in exchange he demands the appointment as ambassador of Panama in US. The intelligence of Panamanian conspirators, the might of US marine and the corruption of a high rank Colombian officer conducted to the independence of Panama. On November 6, 1903, a new treaty Hay-Bunau-Varilla was signed in Washington which foresight that US is the guarantor of the Panama Republic independence and in exchange receive in perpetuity, the use, and control of the site occupied by the Panama Canal and Railroad (approximately a zone 10 miles wide, running from Colon to Panama). The US bought the French equipment and excavation for  $\$40 \times 10^6$  and later, in 1921, paid Colombia  $\$25 \times 10^6$  to recognize the independence of Panama.

In contrast with the French, the Americans considered the canal construction important for the entire nation. When great difficulties appeared the President, the State Department, the Navy or the Congress intervened with promptitude.

The US engineers spent approximately two years in modifying drastically the project. They add three locks (Gatun, Pedro Miguel and Miraflores) and two gravity dams (the Gatun and the Chagres). This modification reduces considerably the hard digging work, especially in Culebra Mountain (in this region the French project demand a canal bed 85 feet deeper). Without diminishing the scientific knowledge and especially the execution skill of US specialists, we must remember that the French engineer Godin de Lépinay as far back as 1879 proposed the Chagres dam, for an identical purpose.

The French work was crippled by malaria and yellow fever as well as the US railroad. The US canal achievement was made possible only by applying all the new findings in the field of medicine (the role of *anopheles* and *stegomyia* mosquitoes in transmission of malaria and yellow fever). As result of the researches of the Cubans physician Carlos Finaly (1902 Nobel Prize) the role of mosquitoes in transmitting the yellow fever was stated in 1880. The Panama Canal was brought to end in August 15, 1914, after ten years of hard work. The strict hygiene imposed to workers resulted in a relative small death toll of about 5,609 persons (approximately a quarter of the deceases in the French period) [1].

The media played generally a negative role; in the first phase (1881-1888), especially for lack of interest. In the second one (1905-1914), looking for the sensational, they exacerbate same minor difficulties pushing the US government to send commission after commission to investigate the situation (Gatun Lake, Chagres Gravity Dam, Culebra Cut).

On the planetary level, the construction is one of the most important and impressive realization. To accelerate the transit, all three locks systems have parallels chambers. For improving the reliability, the lock gates are doubled. To eliminate accidents,

the great vessels movement in the locks is assured with electric locomotives, called “mules”. Because its complexity, the cost of Panama Canal was five times greater than the Suez one.

Politically, the result of the treaty Hay-Bunau was a very odd one. In middle of the Panama state, US control a zone ten miles wide from Colon to Panama (with the exclusion of the two towns). The revenue of the canal, obtained solely by US, was enormous. Such a situation cannot remain without consequences, indifferently of the previous agreements. In the seventy decade of the last century, strong student protests began. To release the situation in September 7, 1977 a new treaty (Carter-Torrijos) was signed. The full Panamanian control became effective on December 31, 1999.

For economic reasons, the ships built beginning with 1970 exceed the Panama dimensions. In consequence, the proposal to expand the Canal (especially the locks) was subjected to a referendum on October 22, 2006 and was approved with a large majority. The upgrading works are under way. They include apart from new locks also a widening of the Culebra Cut and the channel through Gatun Lake.

A general conclusion must be drawn from the realizations presented, namely in the preliminary phase, the possible problems must be analyzed from numerous points of view, at least: technical, medical, biological, social and political.

## 5. Environmental impact

**Suez.** Because Red Sea (salinity 42‰) is 1.2 m higher than east Mediterranean Sea (salinity 38...39‰), the salted water of the Suez Gulf flows into Mediterranean, determining biota migration in the same direction. This phenomenon called “Lessepsian migration” was not very important in the first six decades of the canal existence, because the extremely salted water in the Bitter Lakes (before the construction of the canal they were dry salt deepness, covered with a salt layer 13.2 meters high). In time, the salinity of Bitter Lakes decreased and the biota from Red Sea and Indian Ocean migrated in the direction of Port Said. Up now, approximately 300 species migrated into Mediterranean. Studies evaluating the extent of the ecological changes are in the attention of marine biologist. From the 430 fishes species identified in Mediterranean, approximately 56 are from the Red Sea [6]. In the near future, it must be established if the Lessepsian migration is due to the occupation of unsaturated niche or to a very efficient competition with the local species and whether the migration is beneficial or not. As a curiosity, between 2005 and 2008 thirteen patients aged 26-70 years were poisoned in Israel, with tetrodotoxin, after consuming the immigrant fish *lagocephalus sceleratus* [7].

The small waterway “Nile - Wadi Tumilat – Canal”, completed in 1863, irrigate a previous arid area and allow settlements and agriculture in the adjacent area.

**Panama.** The navigation system uses only river water; the difference being that in previous natural configuration, the river water was delivered only in the Caribbean Sea and in the artificial one, the water is equal divided between Pacific and Atlantic. From this point of view, there are no negative influences upon the environment. The newly created Gatun Lake, with an area twice the Italian Lago Maggiore, substantially altered the aspect of the country by submerging some villages and small towns and in this way affected the local population.

As a general conclusion we can say that the construction of both Suez and Panama canals do not have major negative impacts upon the neighboring ecosystem.

## 6. The Future of Waterways

The Global warming, by melting the Antarctic and Greenland ice caps and other continental glaciers, raises the planetary ocean level [8]. If such a rise is below one meter high, the influences upon both works remain negligible.

If the ocean level rises over this value, the Suez Canal will be shortened because the Red Sea coast will arrive, as in the old times, until Bitter Lakes or even Lake Timsah. If the Mediterranean will be protected against sea level rise, by a dam with locks at Gibraltar, then compulsory the Suez Canal must be also provided with a single stage lock. The place of the lock must be carefully chosen, because the canal is near the junction of the African and Arabian tectonic plates.

For Panama Canal, even a sea level rising with 6 meters will demand minor modifications. Perhaps the reduction of the lifts in locks will even reduce the cost of the passage and shorten the passage time.

If in the future, because of global warming, the ice cap of the Arctic Ocean will melt on a great proportion, than a new route, from East Asians to Western Europe and East America coasts became possible. In comparison with the Panama route, such an Asia-Europe travel saves approximately 9,300 km, and evidently, the importance of Panama Canal diminished dramatically.

## Conclusions

1. Recognizing the importance of Suez Canal, for west-east trade, all the great civilization (Egyptian, Roman and Contemporary) realized the respective waterway. Upon us, Senusret II (pharaoh through 1897-1878 BC) was the first who carried out such a canal.
2. Even Columbus who searched the secret waterway through the Panama Isthmus recognized the importance of Panama Canal. When the idea of such a secret waterway was abandoned, the emperor Charles V of Spain gives the order to study the possibility of constructing a canal along the river Chagres.

3. A general conclusion arose from both realizations, namely for such important works, in the preliminary phase, the possible problems must be analyzed from numerous points of view, at least: technical, medical, biological, social and political.
4. The technical problems to be solved were more difficult for Panama than for Suez; as a result, the cost was five times higher.
5. The influence of the works upon the environment was not significant. The Suez Canal determined the Lessepsian migration. Marine biologists are studying the phenomenon to decide if it is a positive or a negative one. At Suez, a small arid area was irrigated allowing settlements and farming. For Panama there were no significant influences upon environment.
6. The global warming will affect both works. The ocean level rise will inundate the actual Suez Canal possible until Lake Timsah. To maintain the actual configuration of the zone a lock system can be disposed near the Suez Port. The level rising will not disturb the running of the Panama Canal. The melting of the North Pole ice cap will create possibilities for ships to navigate through the Arctic Ocean, especially in summer. Therefore, the importance of the Panama Canal will have a small decrease.

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