General Overview
HISTORY
of the
PANAMA CANAL

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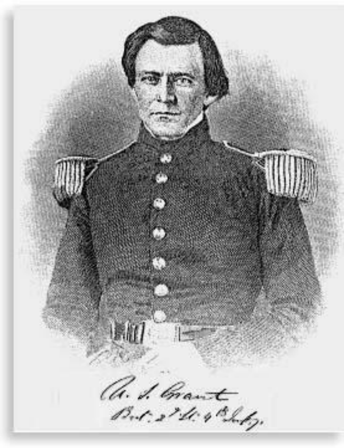
for the

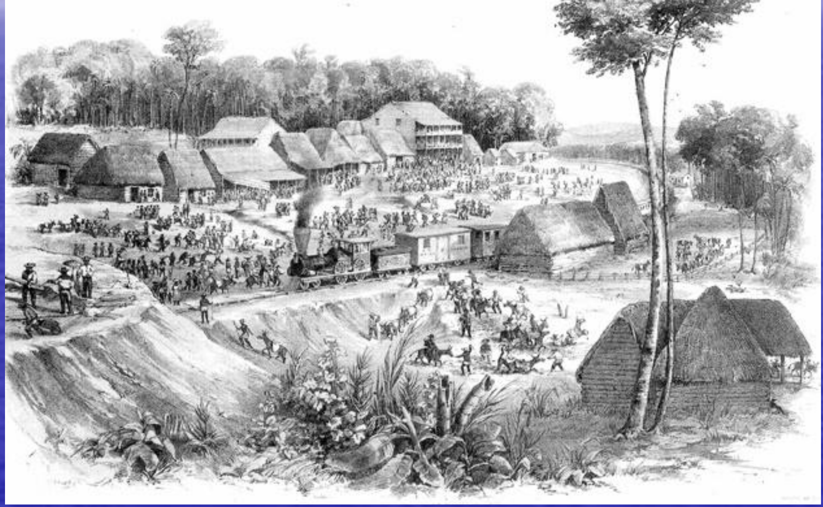
Our story begins with the 50,000 gold seeking '49'ers cross the Panamanian Isthmus between 1849-59

The Panama Railroad earned money even while under construction



Lt U.S. Grant - 1852

Summit of the Panama Railroad at Culebra in 1854

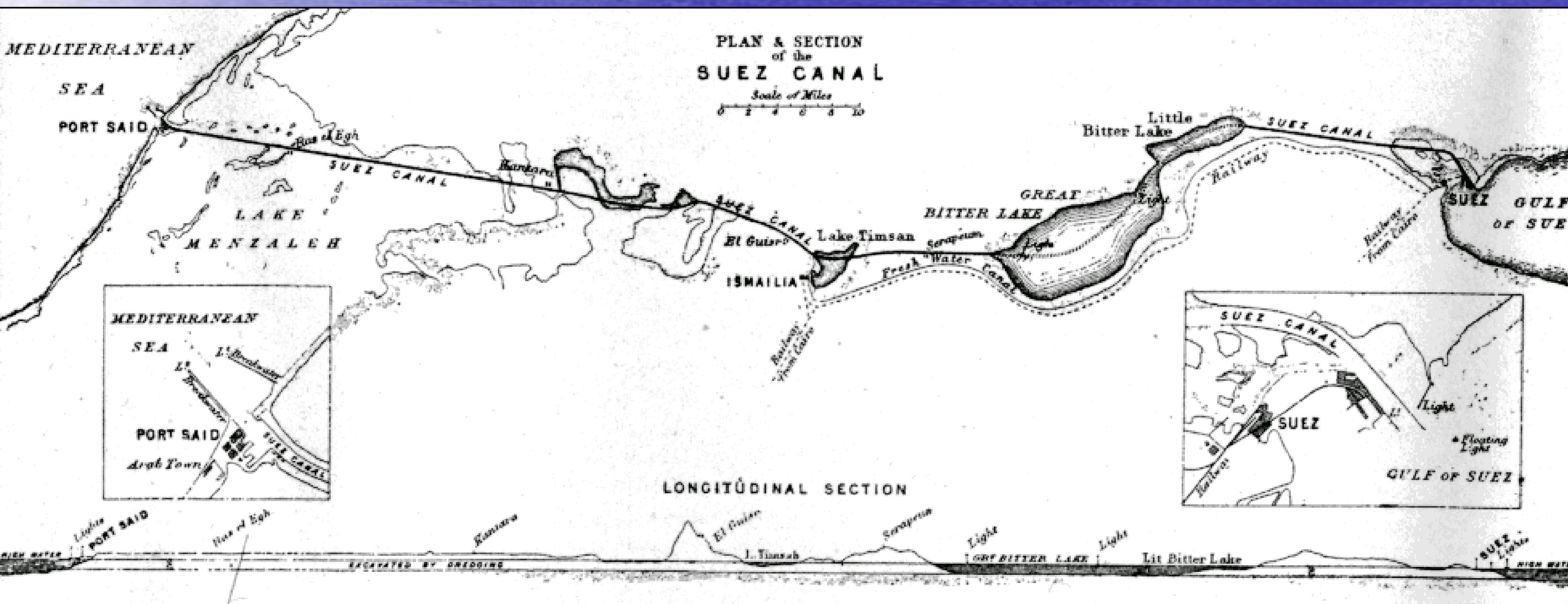


After conversion to standard gage in 1884

- Stimulated by thousands of Americans that crossed the Panama Isthmus during the California Gold Rush, the **Panama Railroad** was built between 1850-55, becoming the most profitable business venture on the New York Stock Exchange in the 19th Century.
- Army Lieutenant Ulysses S. Grant was among those who led his soldiers across the fever-infested isthmus on their way to California in 1852

Ferdinand de Lesseps (1805-94) was a career French diplomat who was posted to Alexandria, Egypt in 1832-37. At that time he conceived the idea of excavating a canal between the Red Sea and the Mediterranean. He retired from the diplomatic corps in 1853 and moved to Egypt the following year. By 1856 he had engaged two engineers to draw up suitable plans for a canal, and after convincing others of its practicality, construction commenced in 1859.

PLAN VIEW OF CANAL ROUTE

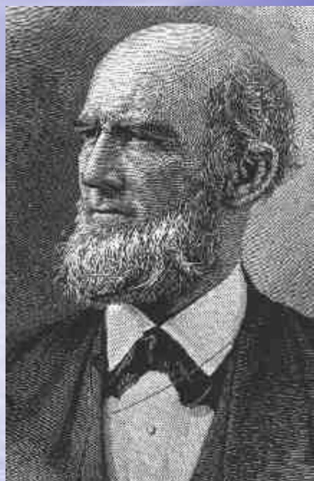


ELEVATION ALONG SUEZ CANAL ROUTE

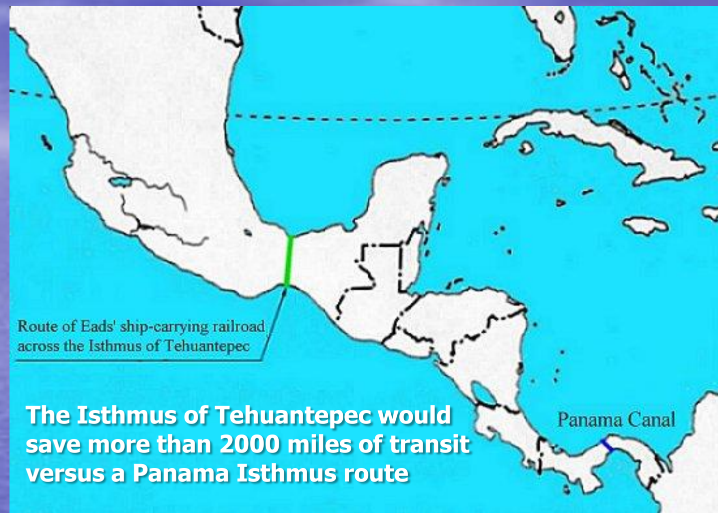
Suez Canal 1859-69

The 102 mile long Suez Canal was a massive, but uncomplicated excavation job, involving sand. It's successful completion inflated de Lesseps and the French with considerable overconfidence

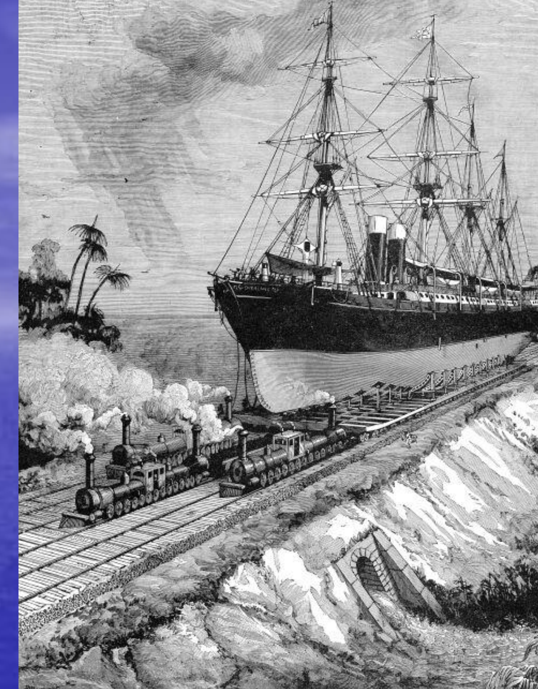
Ead's Tehuantepec Interoceanic Ship Railway



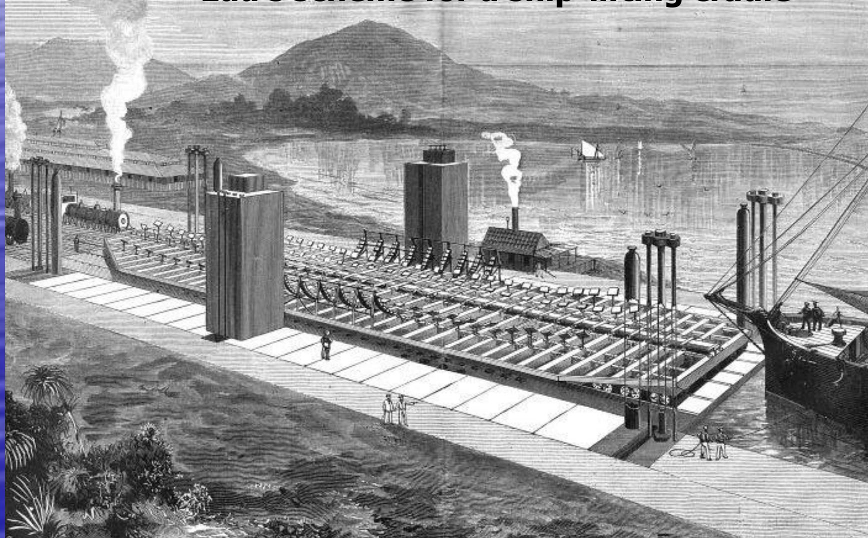
James B. Eads
(1820-87)



Steam locomotives pulling a cradled vessel across the isthmus



Ead's scheme for a ship-lifting cradle

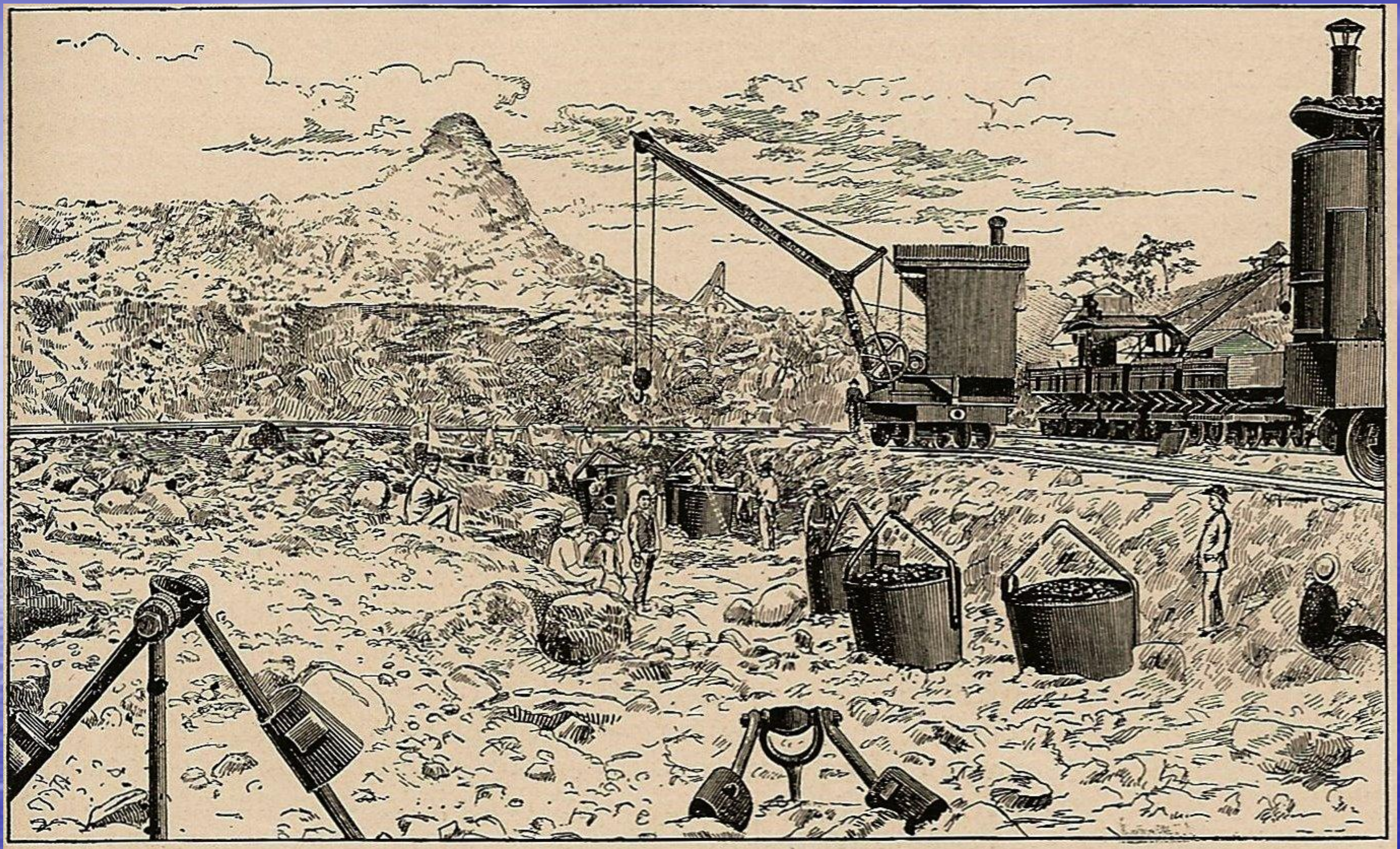


- During the Panama Canal Congress of 1879 in Paris, American Engineer James B. Eads proposed the construction of a 140-mile long interoceanic ship railway across the Isthmus of Tehuantepec in Mexico, saving over 2,000 miles over the Panama Route. He developed detailed plans to support his scheme , claiming it would cost about half of what the French were proposing for a sea-level canal across the Panama Isthmus.
- In 1881 he stated he would finance the project himself, asking Congress to guarantee his dividend at 6% interest for 15 years. He died in 1887, never realizing his dream of completing the project.

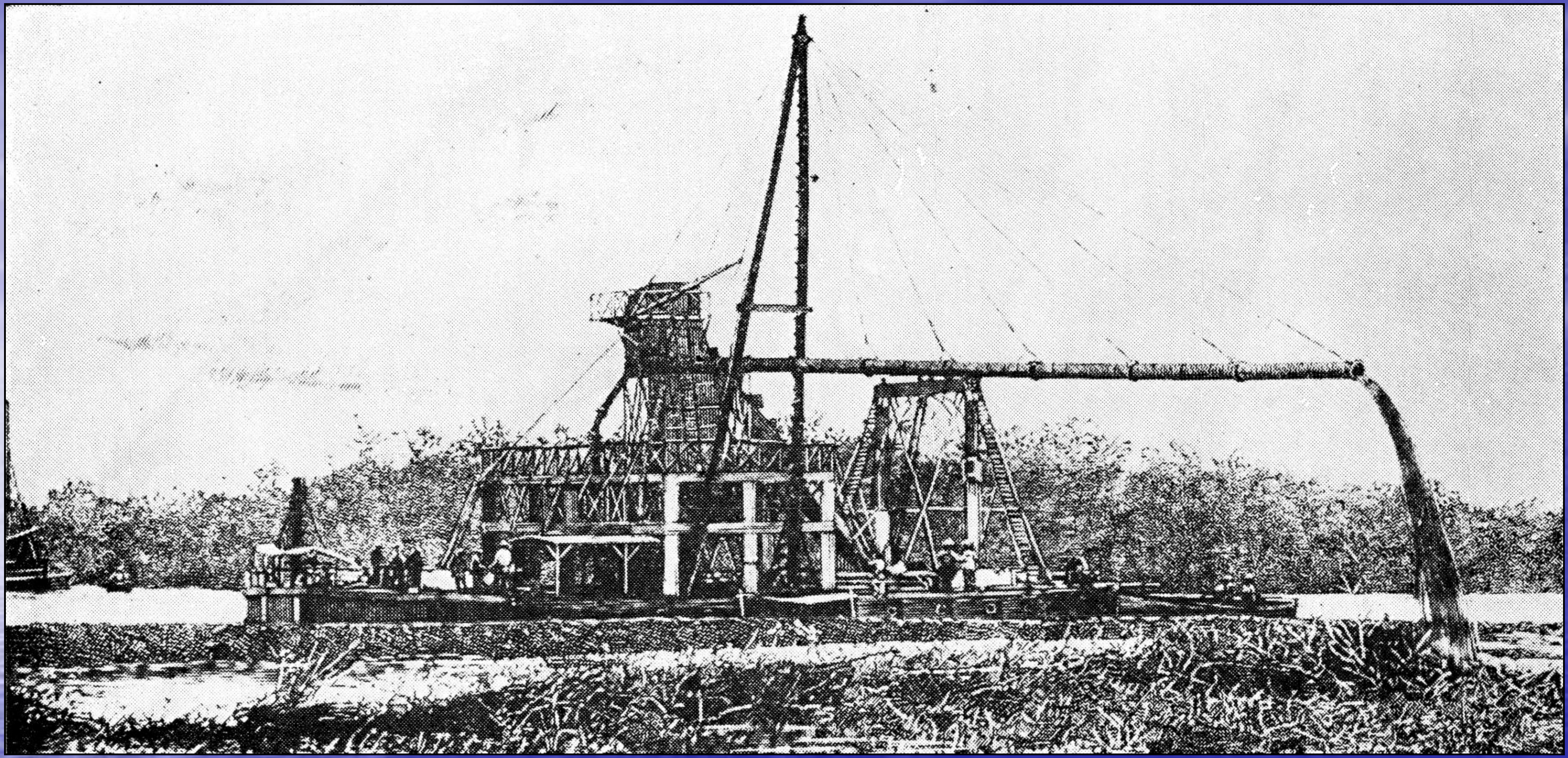
1880-89 and 1895-96 The French Descend Upon the Panamanian Isthmus

They dig with vigor, twice, but lose 5,600 lives

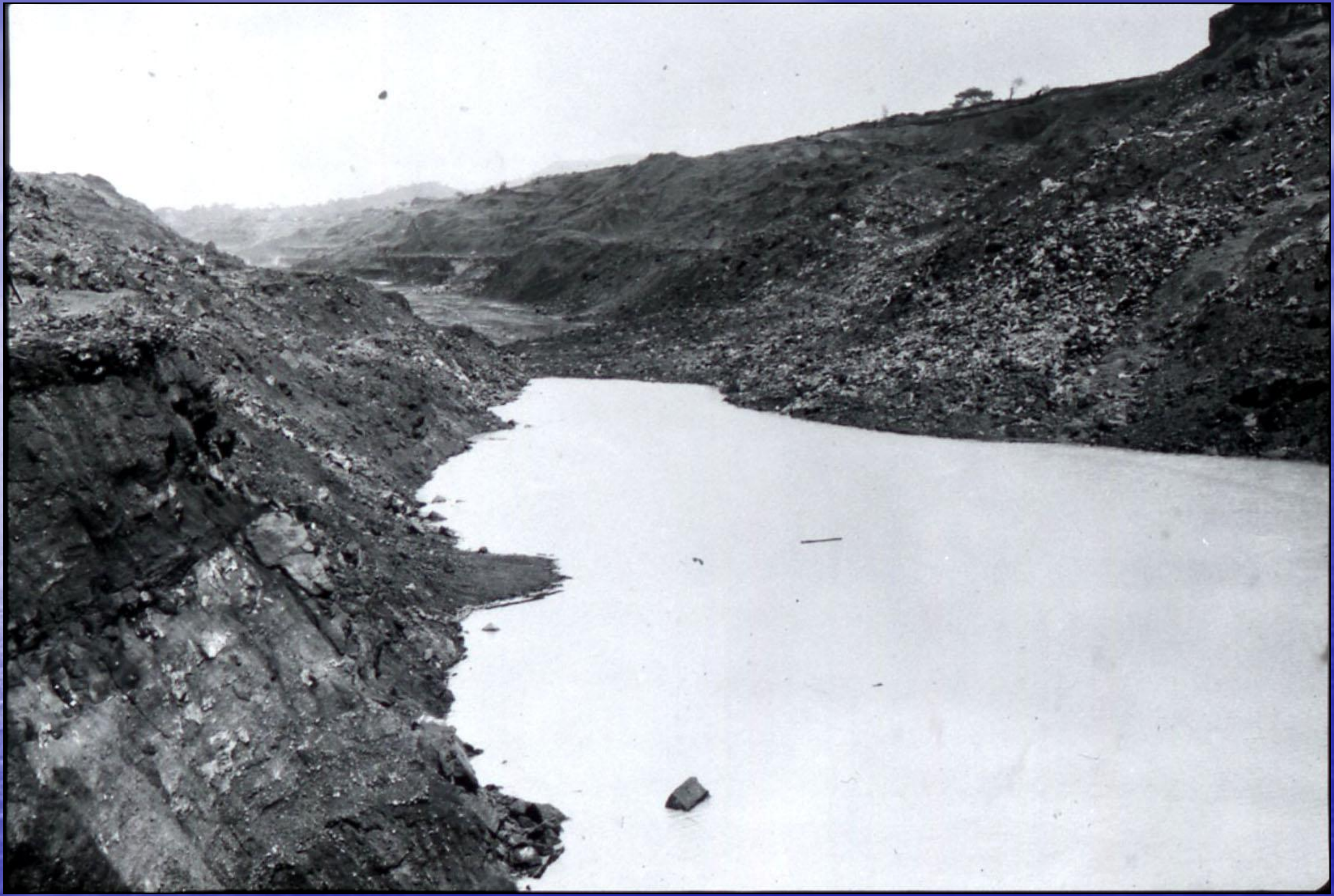
- The French arrived on the Isthmus in 1880 intending to excavate a sea level canal. They began excavating the highest cuts, across the Continental Divide, in 1884.



- July 1886 lithograph showing French muck trains, churn drills, and crane buckets being employed in their excavations along the eastern side of the Continental Divide



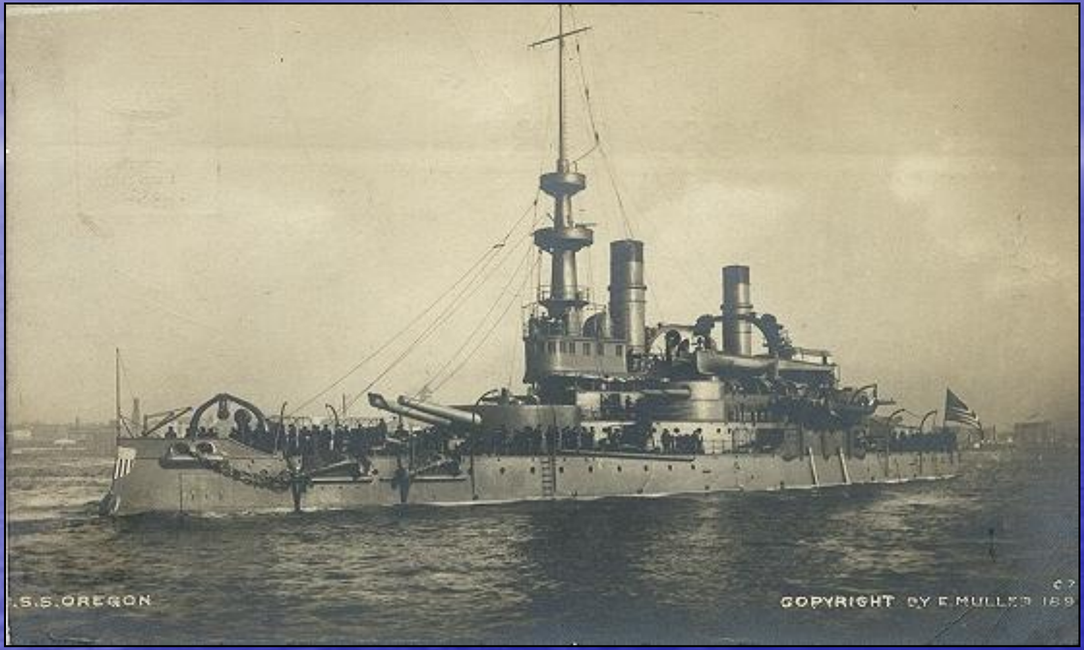
- **High technology:** The French proved both clever and innovative in deploying new types of equipment. This shows a floating dredge they assembled in 1883 to excavate the approach channel at Cristobal, on the Atlantic side of the Panamanian Isthmus.



- Landslides began to plague the French excavations in the vicinity of Cucaracha and Culebra in 1886, severing their trunk rail lines. In addition to slides, they fought a losing battle with Yellow Fever and Malaria, and went bankrupt in 1889.

- **A second French company returned in 1895, but they were insufficiently capitalized, and operated for just over a year, The canal excavations then laid dormant until the United States purchased their license and assets in 1903, for $40 million.**

A canal was crucial to the development of a two-ocean American Navy



- The battleship **USS Oregon (BB-3)** was the first capital ship built on the west coast, between 1890-96. Soon after the battleship *Maine* exploded in Havana Harbor, the Oregon sailed 14,000 miles from San Francisco to Santiago, Cuba in 66 days.
- The *Oregon*'s 9-1/2 week delay could have been cut to just three weeks if the canal across Panama had been operational…
- This persuaded Congress to purchase the failed French operations in Panama and complete the canal. The other important factor was the new American presence in the Pacific Basin, from the possessions gained during the Spanish American War.

1899 map of Nicaragua

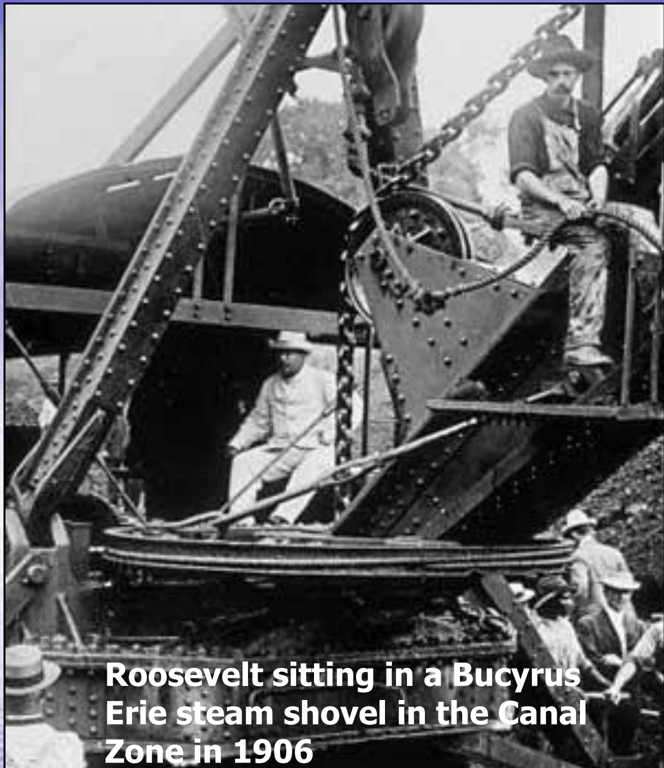
- At the turn of the 20th Century Americans favored a canal through Nicaragua because roughly half of those emigrating to California crossed over to the Pacific along this route and it looked easy on a map. Lake Nicaragua looked similar to Lake Suez along the Suez Isthmus.
- But, a sea level canal was impractical because it would drain the lake, and there were active volcanoes in Nicaragua.

The postage stamp that altered history….

- President Teddy Roosevelt favored purchasing the French canal excavations, but the U.S. Senate preferred a canal in Nicaragua, where considerable American skill and effort had already been expended
- In May 1902 the Nicaraguan volcano Momotombo erupted
- Panama advocates warn that a Nicaraguan canal might be destroyed by fire and lava
- Nicaragua advocates responded that Panama’s earthquakes were just as bad
- Philippe Bunau-Varilla (1859–1940) mailed a letter to every U.S. Senator with a Nicaraguan postage stamp, showing the Momotombo volcano erupting …
- The American Senators then voted 42 to 34 in favor of Panama

The moving force…

Teddy Roosevelt



Roosevelt sitting in a Bucyrus Erie steam shovel in the Canal Zone in 1906

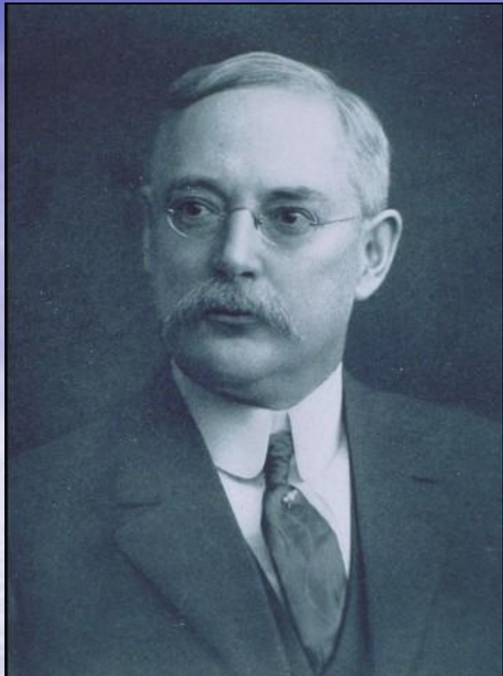
- **President Teddy Roosevelt viewed the Panama Canal as vital to America's destiny as a two ocean naval power, able to service and protect our new holdings in the Pacific Basin. He pushed Congress to acquire the French rights to the Canal.**
- **Part and parcel of this arrangement was supported Panama's independence from Colombia – which he believed would strengthen American influence on Central and South America. He sent US warships to both sides of the Isthmus and sent in troops to protect the Panama Railroad, as a show of strength to the Colombians**
- **These actions resulted in Panama being able to declare independence from Colombia on November 3, 1903 and, not surprisingly, the Panamanians granted the Canal Zone to the US in perpetuity (it was not ceded back to Panama until 1999).**

1903
The Americans pay the French $40 million and take over

thinking…

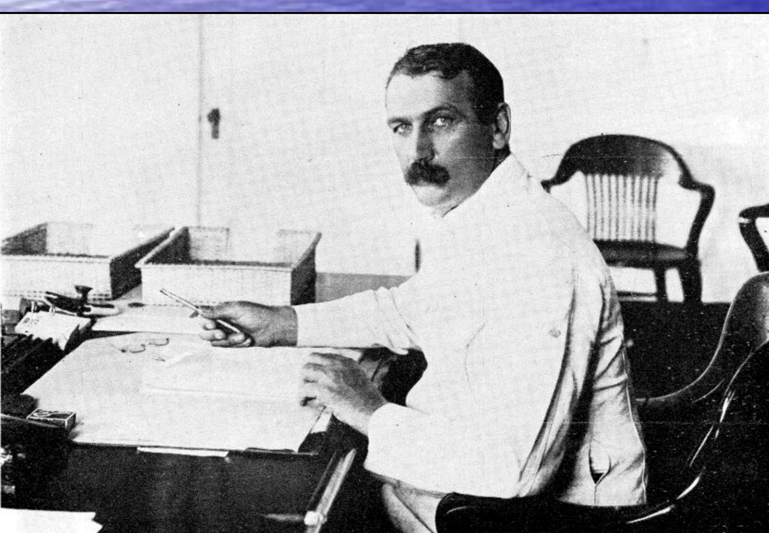
"It's just a big railroad job"

Two ASCE Presidents named John F.



John F. Wallace

- Wooster University trained civil engineer **John F. Wallace** served as President of the American Society of Civil Engineers (ASCE) in 1900. In May 1904 he was named Chairman and Chief Engineer of the Isthmian Canal Commission. He arrived in Panama in July 1904 and gradually grew to doubt the ability of Army physicians to combat malaria and yellow fever, resigning 11 months later, in June 1905.



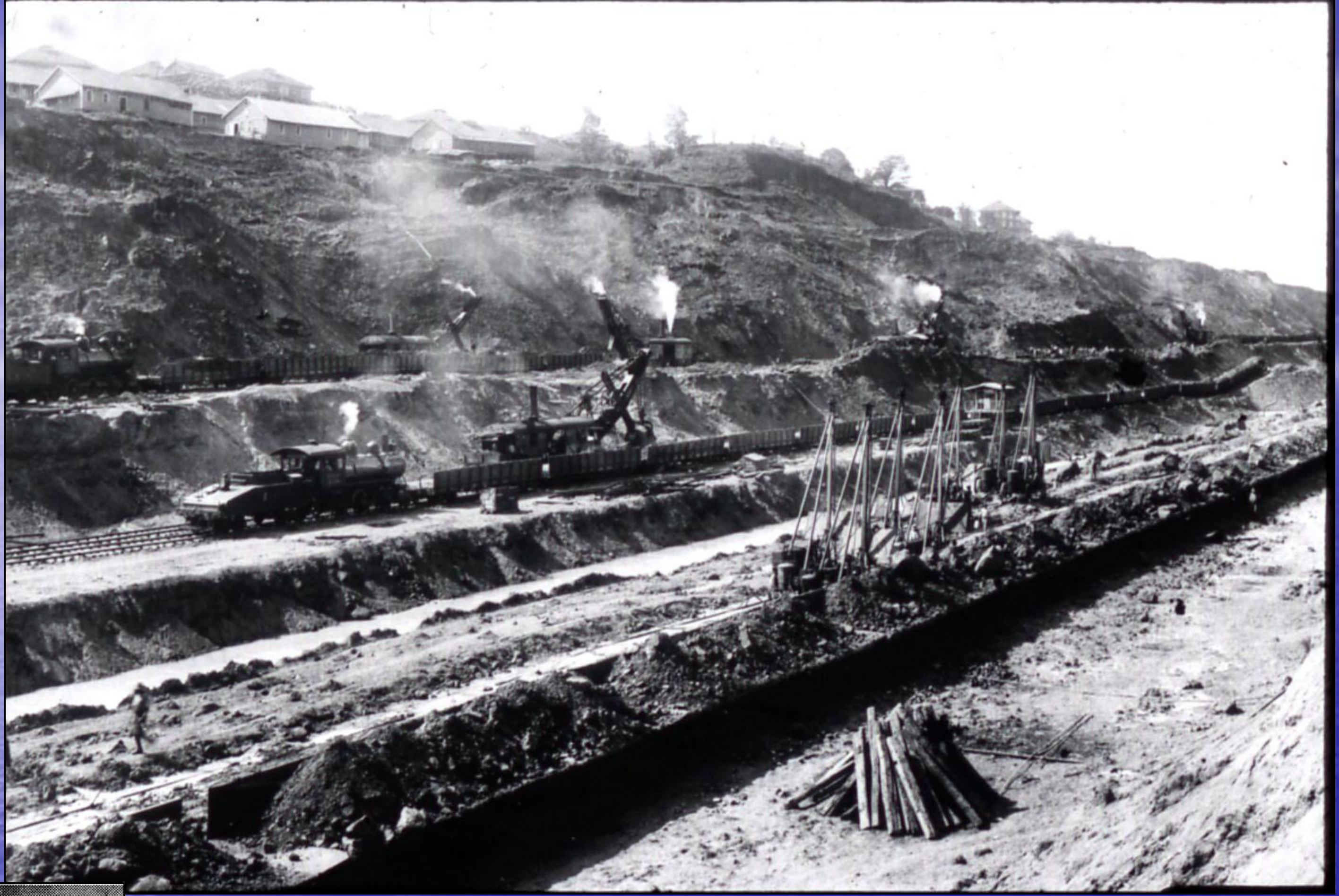
John F. Stevens

- Self-taught railroad engineer **John F. Stevens** succeeded Wallace in June 1905 and fully supported William Gorgas's efforts to combat disease. He wrestled with the overall design concepts and was ably assisted by 27 yr old Ralph Budd, who had worked fro him on the Rock Island Railroad in Kansas City. He resigned on February 26, 1907, greatly infuriating Teddy Roosevelt. Stevens served as ASCE President in 1927.

America's Greatest Contribution was in the arena of sanitation

The female anopheles mosquito

- **William Crawford Gorgas** was the son of Confederate General Josiah Gorgas, Chief of Ordnance. He became a US Army physician in 1880, and while stationed at Fort Brown, Texas (1882-84) almost died of yellow fever.
- He is best known for his work in Florida, Cuba, and Panama in abating the transmission of yellow fever and malaria by controlling the mosquitoes that carry them at a time when there was considerable skepticism and opposition to such measures.
- He later became the 22nd Surgeon General of the U.S. Army during the First World War (1914–1918).



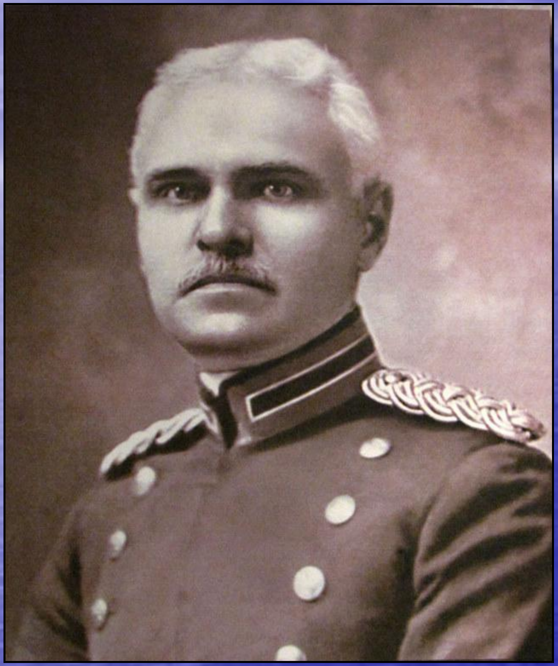
- **John F. Stevens** conceived the "minority plan" to construct a locked canal, using water from the Chagres River to create a vast inland lake.
- This reduced the required depth of excavations by 70 feet. The plan was favored by Teddy Roosevelt and approved by Congress on June 29, 1906.

- **Stevens said the canal job was all about *logistics, logistics, and logistics…* This shows the morning work train delivering Caribbean workers. Note the faulted contact between the resistant hill and adjacent slopes.**

- The 45 degree side slopes of the massive cuts can be appreciated in this view, as the Americans begin to attack the Continental Divide.

- Canal side slopes progressing on schedule at Culebra. Note suspension bridge across the chasm, to carry workers to the opposite side.

The Army Corps of Engineers assumes control in 1907



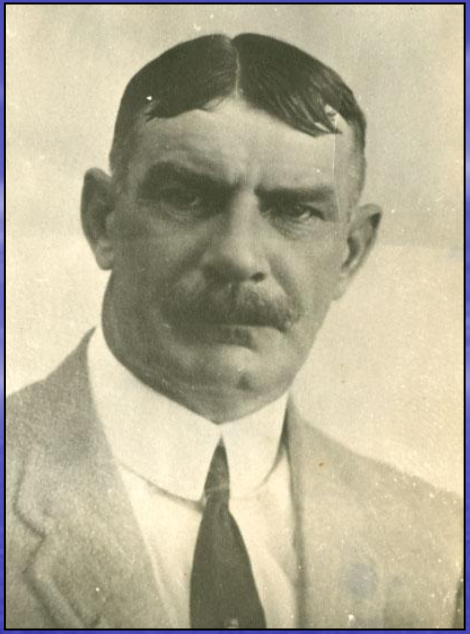
Goethals

Hodges

- On March 4, 1907, *Lt Colonel George Washington Goethals (USMA 1880)* was appointed by President Roosevelt Chairman and Chief Engineer of the Isthmian Canal Commission, a position that would consume him for the next 7-1/2 years.
- Goethals was ably assisted by *Lt Colonel Harry F. Hodges* (USMA 1881) as the project's Chief Design Engineer, who supervised the design of the project's massive locks. Both men were subsequently promoted to Major General.

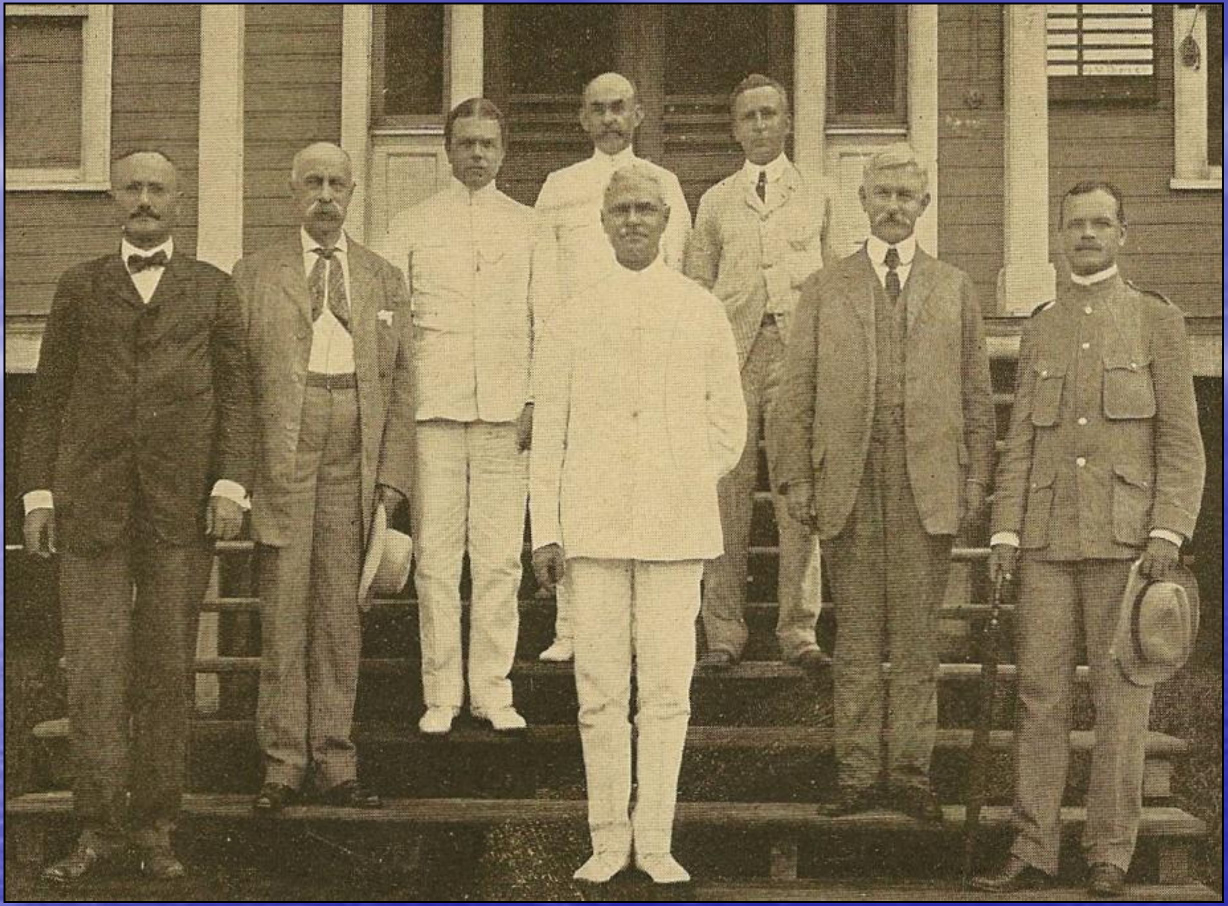
Sibert

Gaillard

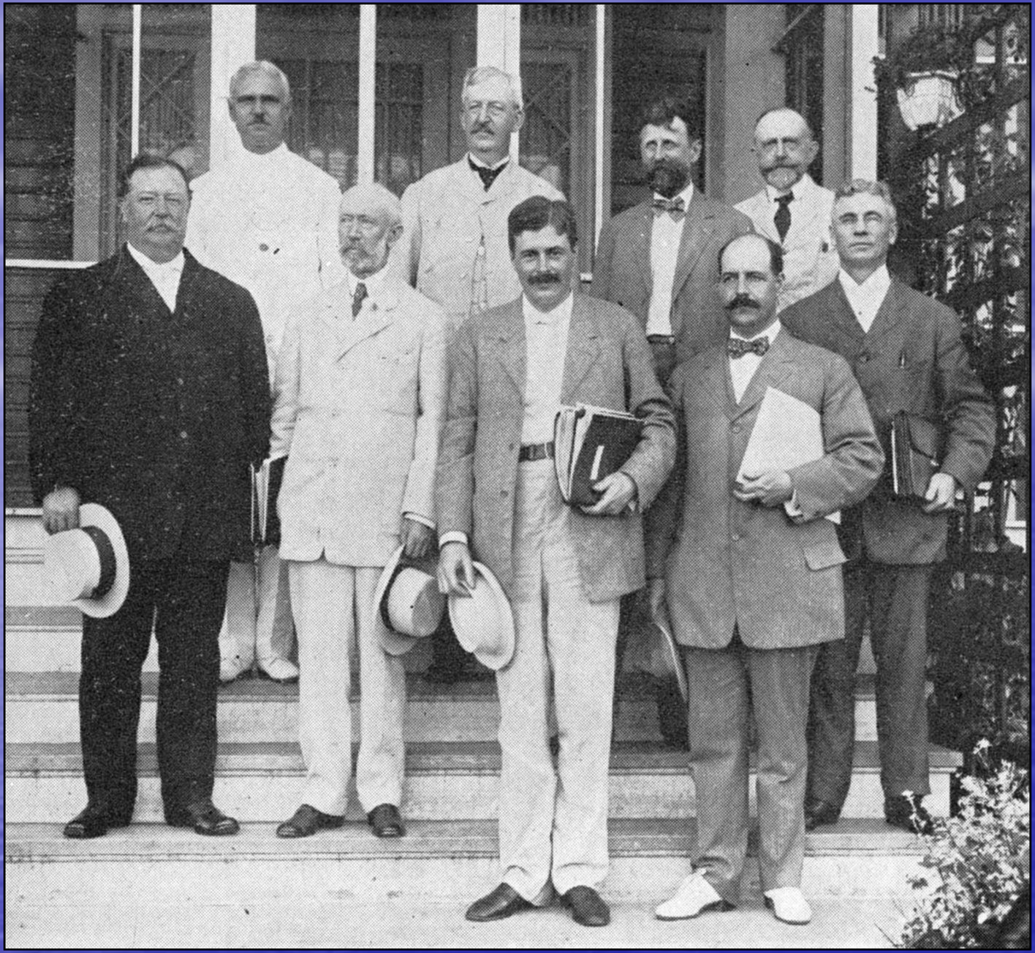


Williamson

- **The Atlantic Division, under Major William Sibert (USMA 1884), was responsible for constructing the approach channels and three massive locks at Gatun, on the Atlantic side, as well as Gatun Dam and reservoir. Major David D. Gaillard (USMA 1884) oversaw the expansive Central Division from Culebra Heights, which encompassed 40 miles of work, including all the landslides. Civilian engineer Sydney B. Williamson (VMI 1884) oversaw operations of the Pacific Division, which included 9 miles of canal and approach channels, the Pedro Miguel and Miraflores Locks, and a three mile long breakwater.**
- **Gailliard died of a brain tumor in December 1913. Sibert was subsequently promoted to Major General, and chaired the *Colorado River Commission* that oversaw the design of *Hoover Dam* in 1928-31. Williamson went on to serve as Chief of Construction for the Reclamation Service, as a Lt Colonel in France during WW1, and on the *Interoceanic Canal Board* from 1931-35, when a new Nicaraguan Canal route was examined.**

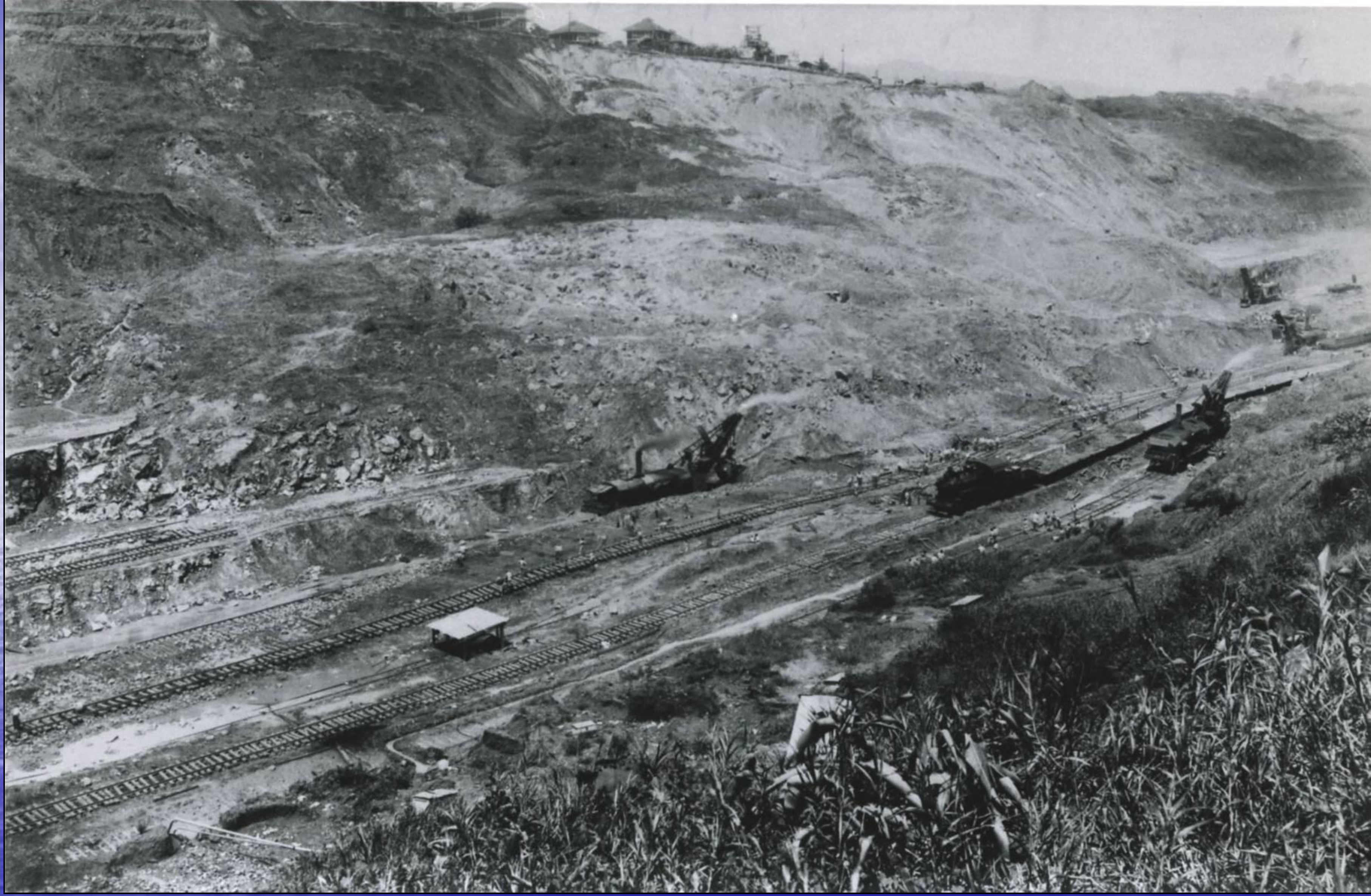


- When the Army took over the project, they retained the **Isthmian Canal Commission**, which provided third party review of the transportation, sanitation, and administrative issues involving the canal's construction. In 1910 this group was comprised of Lt Colonels Goethals and Gorgas, Majors David D. Gaillard and William L. Sibert, Rear Admiral Harry H. Rousseau, Joseph C.S. Blackburn, and Jackson Smith



- The engineers comprising the technical advisory arm of the Isthmian Canal Commission became the Special Board of Consulting Engineers (SBCE), shown here in 1909, while visiting the Gatun Dam and Locks. From left: War Secretary William H. Taft, Colonel George W. Goethals, Frederick P. Stearns, Henry A. Allen, Arthur Powell Davis, James D. Schuyler, Isham Randolph, John R. Freeman, and Allen Hazen

- As the excavation deepens, the side slopes started caving in on the main excavation. This shows the beginning of the **East Culebra Slide**.



- Shovels begin attacking a similar problem, which they name the **West Culebra Slide**, on September 12, 1912.

- Outfall discharge from the suction dredges. The dredge tailings were dumped into rock-lined dikes, covering an area of several square miles.

- The waste muck was conveyed by rail cars and dumped into enormous fill piles at the coasts.

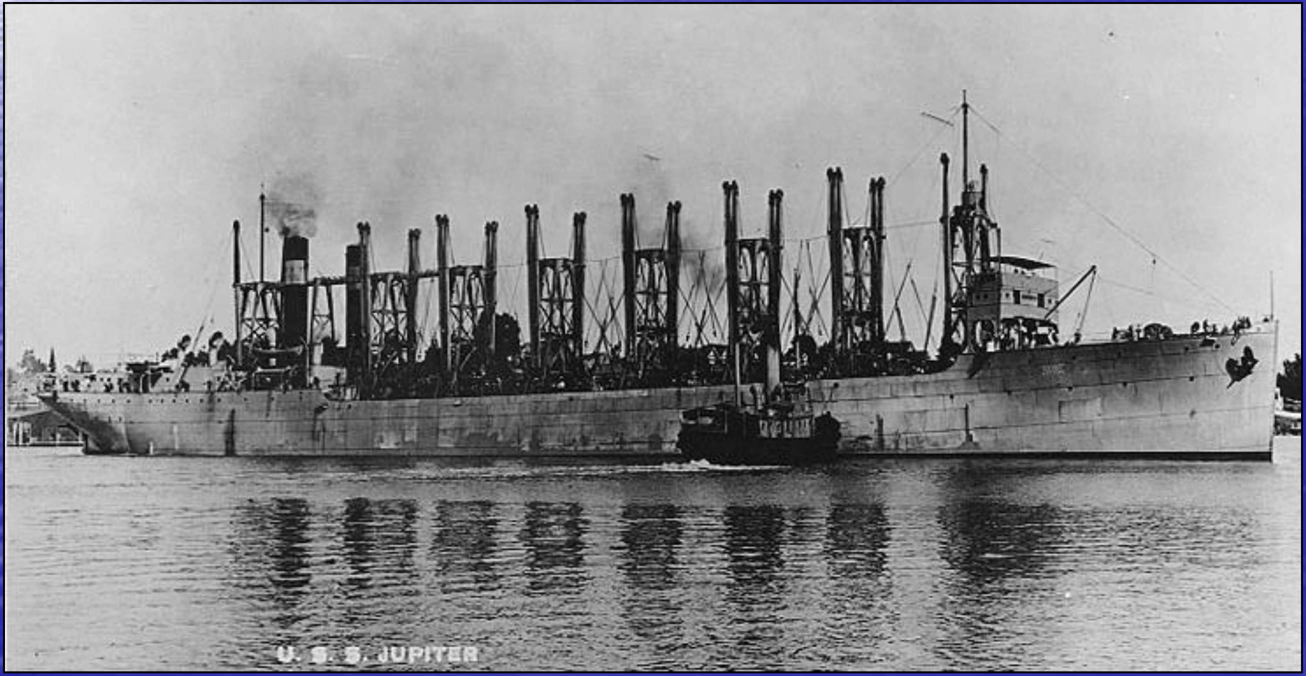
- **Another view showing size of the rail dumped waste pile on the Pacific side.   Note locomotive for scale.**

- **Closing in on the finish line.** Looking into the gapping hole at the Continental Divide on May 17, 1913. Note 0.5:1 side slopes.
- The Americans ended up excavating 245 million yds^3, almost equal portions being dredged below water and excavated in the dry.

August 1914: The Canal Opens for Business as the First World War erupts

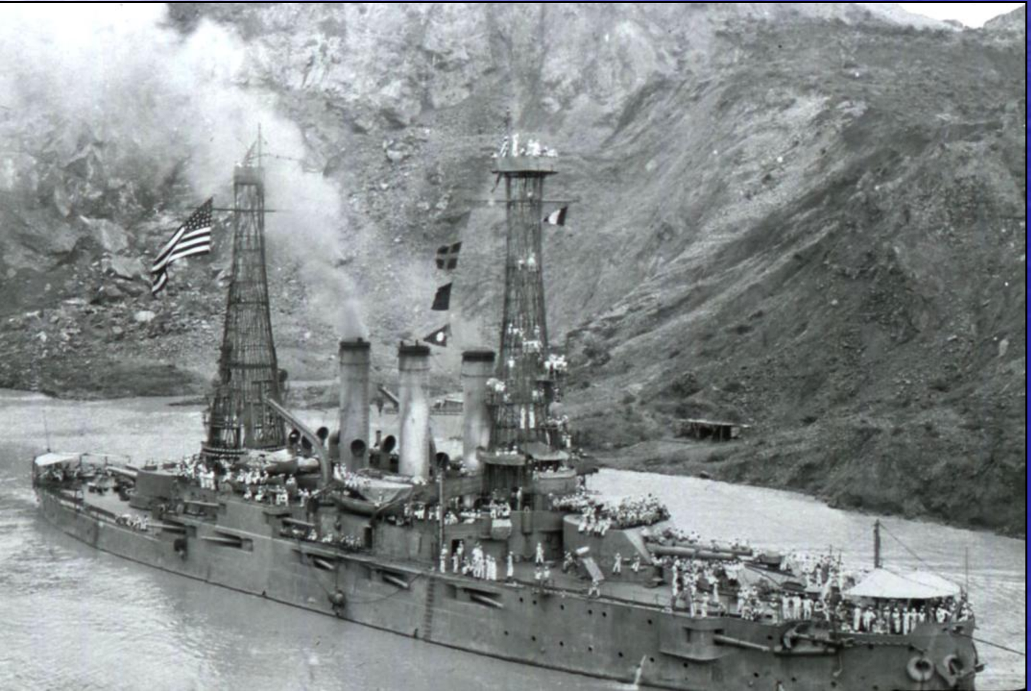
Trumpeted as an American Triumph, but little used and often closed by landslides during its first five years

The S.S. Ancon makes the historic first passage through the canal, from the Atlantic to the Pacific on August 15, 1914. Note dredges working along the toe of the Cucaracha Slide.



The Navy collier USS Jupiter, built at Mare Island on the West Coast, made the first west-to-east transit of the Canal, a few days later. She was the Navy's first surface vessel using a turbo-electric propulsion system, and was later converted to the Navy's first aircraft carrier, USS Langley, between 1919-22.

- Dipper and suction dredges working the toe of the East Culebra Slide, just north of the Continental Divide, on July 3, 1916

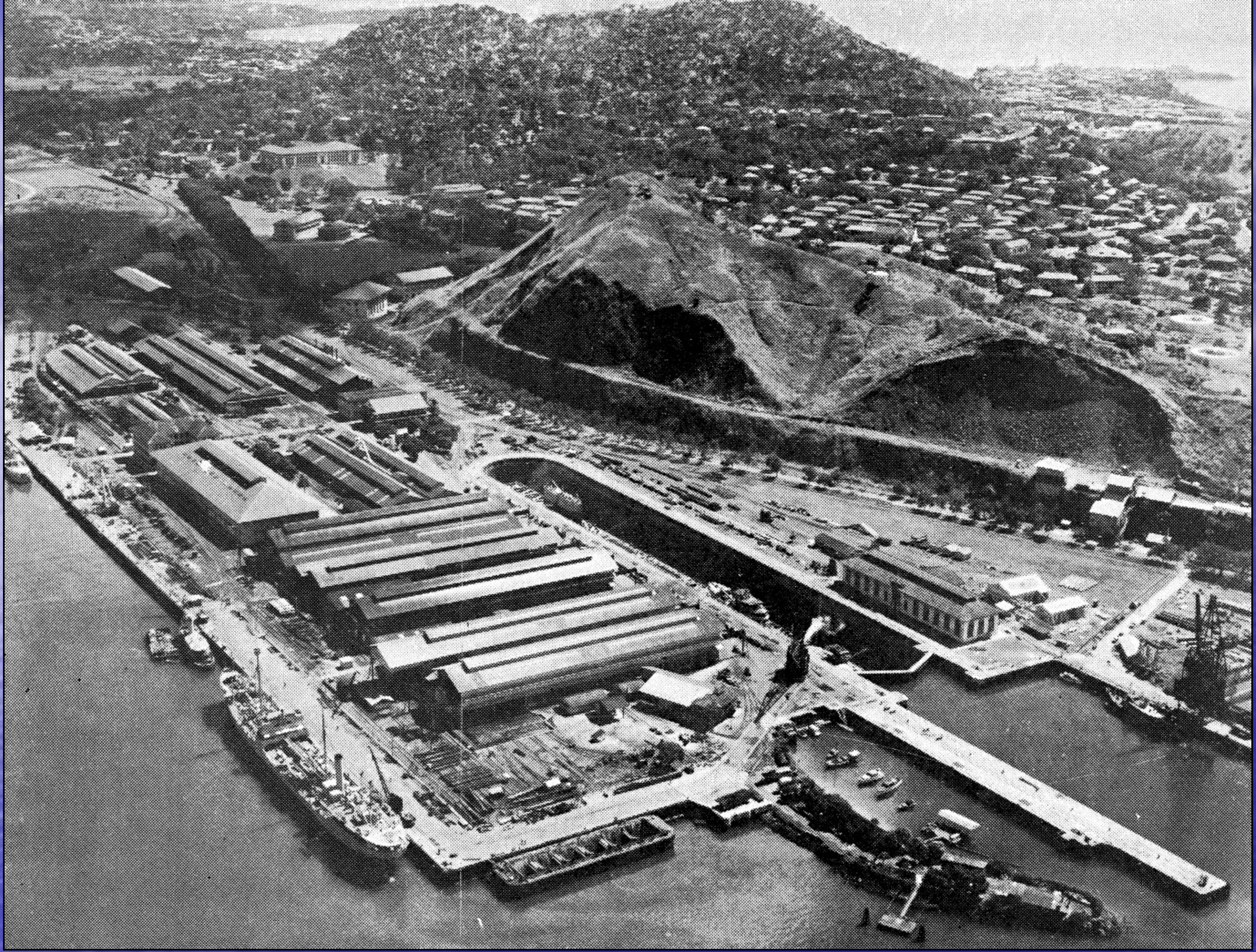


Strategic Import to the American Navy

- The Canal was immediately perceived as a enormous asset to project American influence on the Pacific Basin, where America had gained numerous far-flung possessions during its whaling days, Seward's purchase of Alaska, and the former Spanish possessions ceded to the US after the Spanish American War.
- There were only two capital ships ever built on the Pacific Coast prior to the Second World War (USS Oregon and USS California)

The US Pacific Fleet was enlarged throughout the inter-war period, from 1919-41

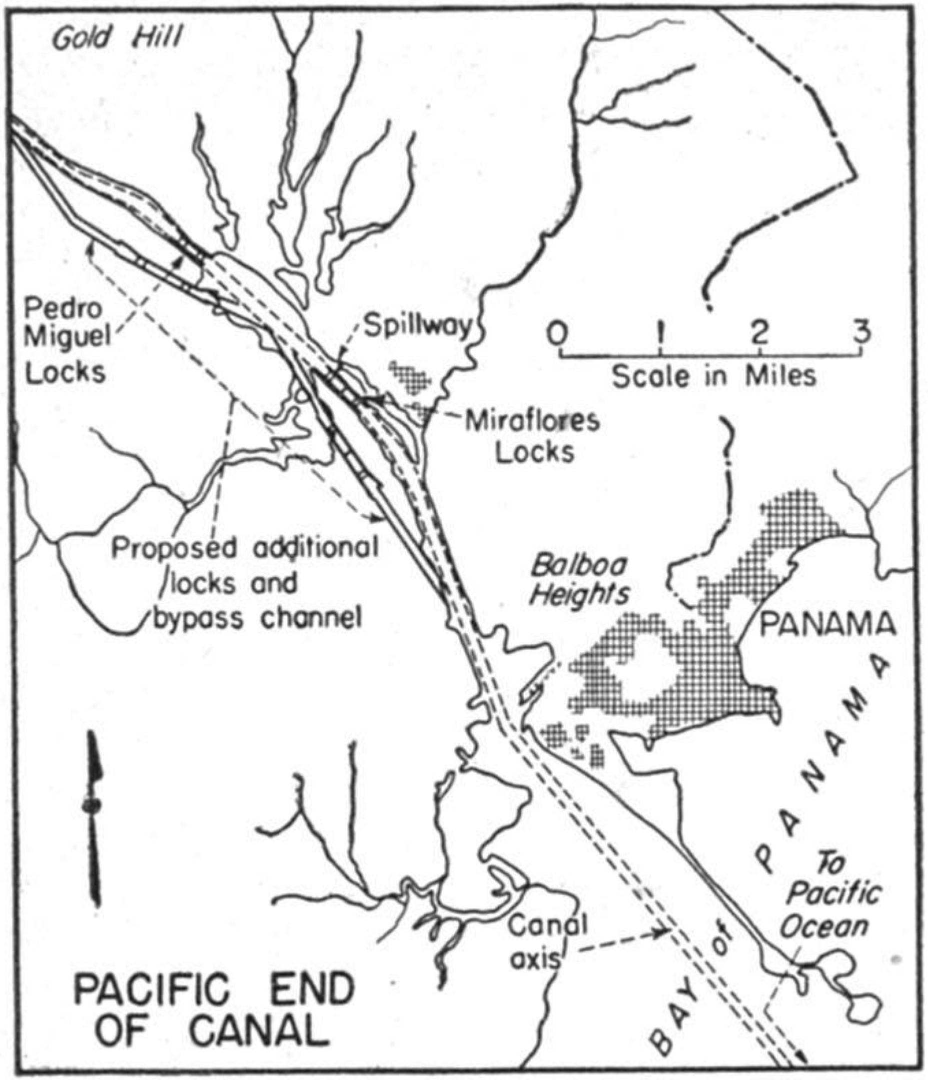
Fleet exercises often involved a friendly force defending the canal from attack by an aggressor force

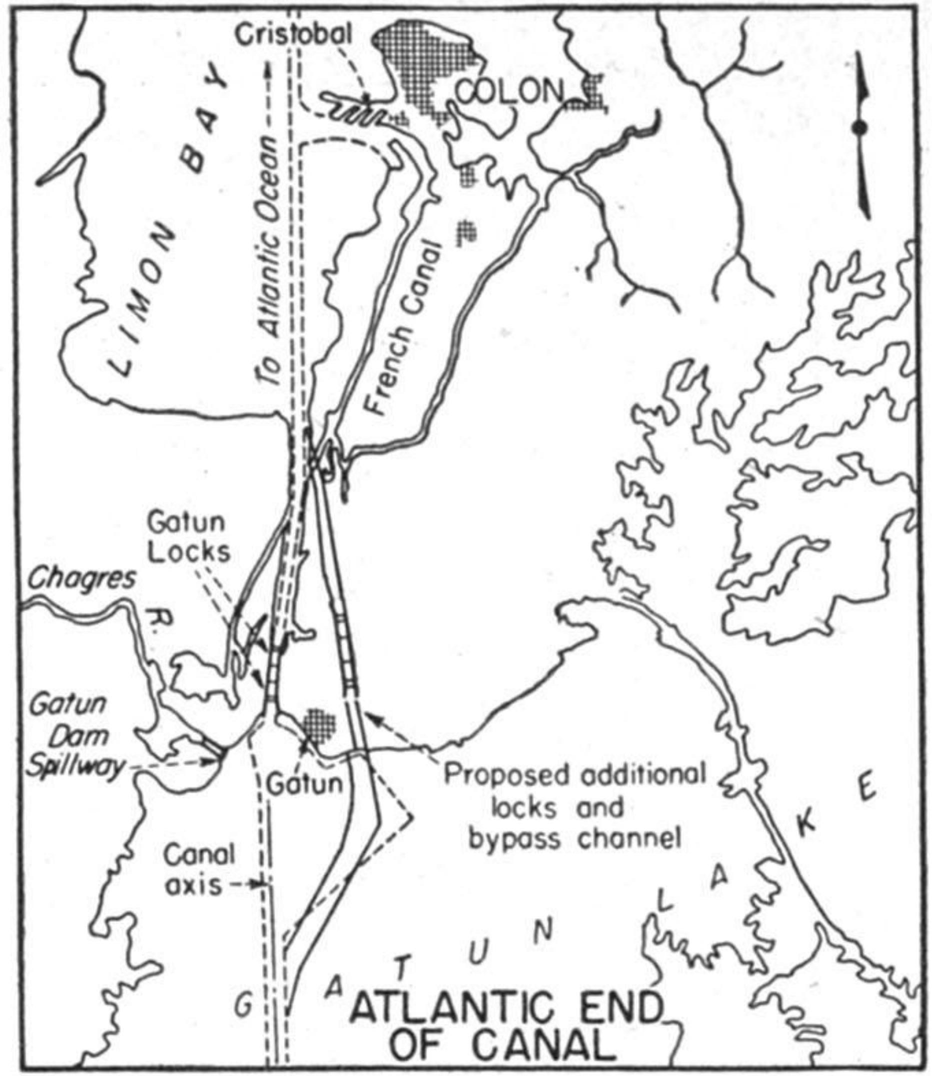


- Aerial oblique view of the Canal's Mechanical Division Shops and the massive drydock constructed at Balboa during the First World War, as viewed in 1938.

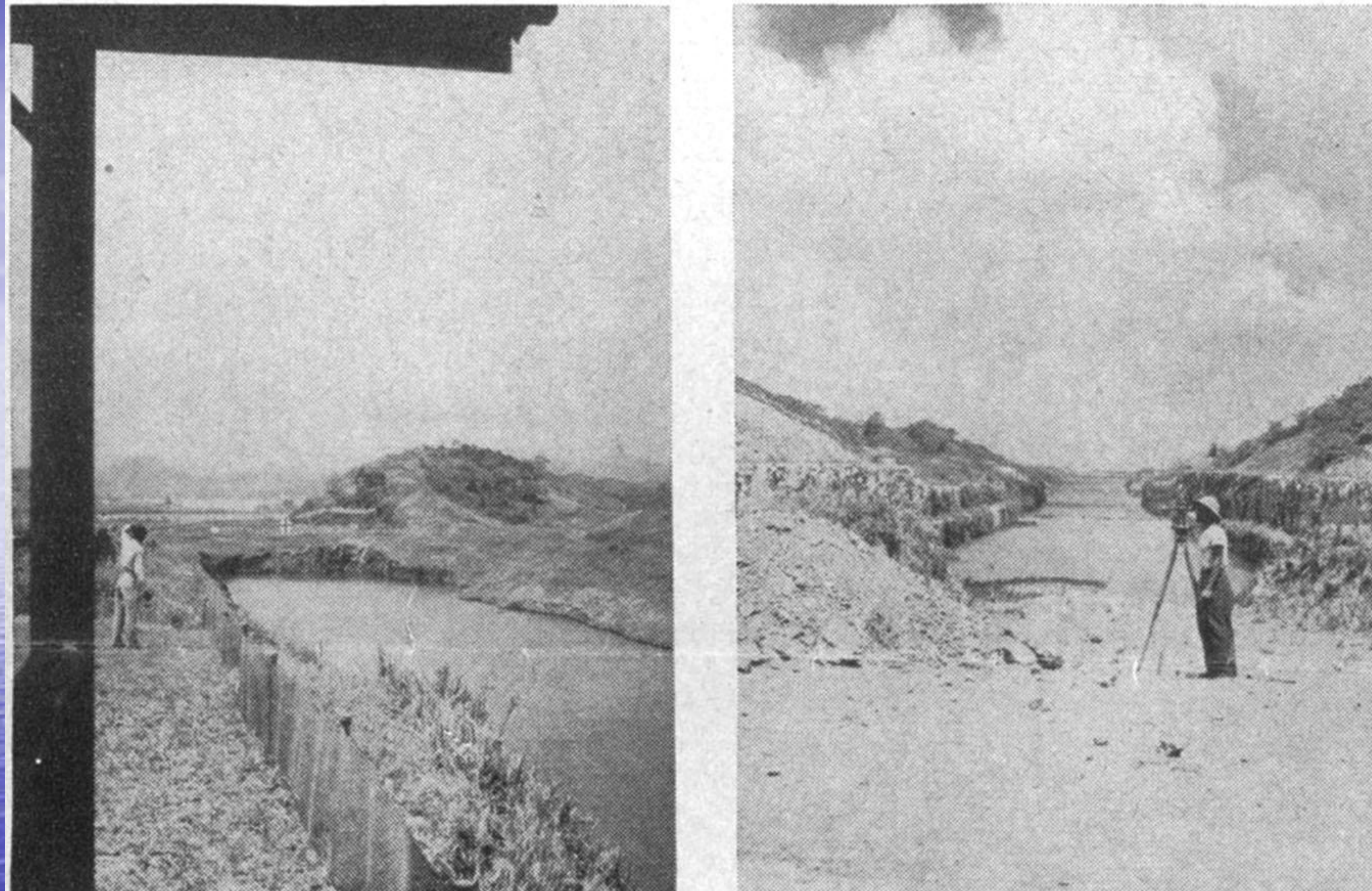
The Third Locks Project 1939-42

The massive excavations for the Third Locks Project are usually mistaken for the old French excavations at either end of the canal





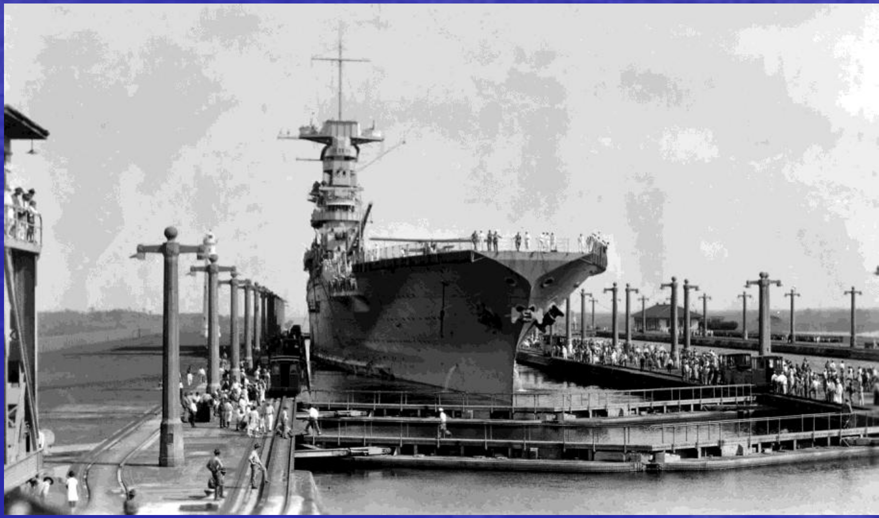
- The **Third Locks Project** was authorized by Congress with an appropriation of $277 million in the spring of 1939. It proposed to enlarge the canal's locks; from 1050 to 1200 ft long, from 110 to 140 ft wide, and from 31 to 45 ft deep.



- **Excavations for the Third Locks at either end of the canal were essentially completed between 1939-42, but the project was shut down prematurely shortly after the attack on Pearl Harbor, and never completed.**

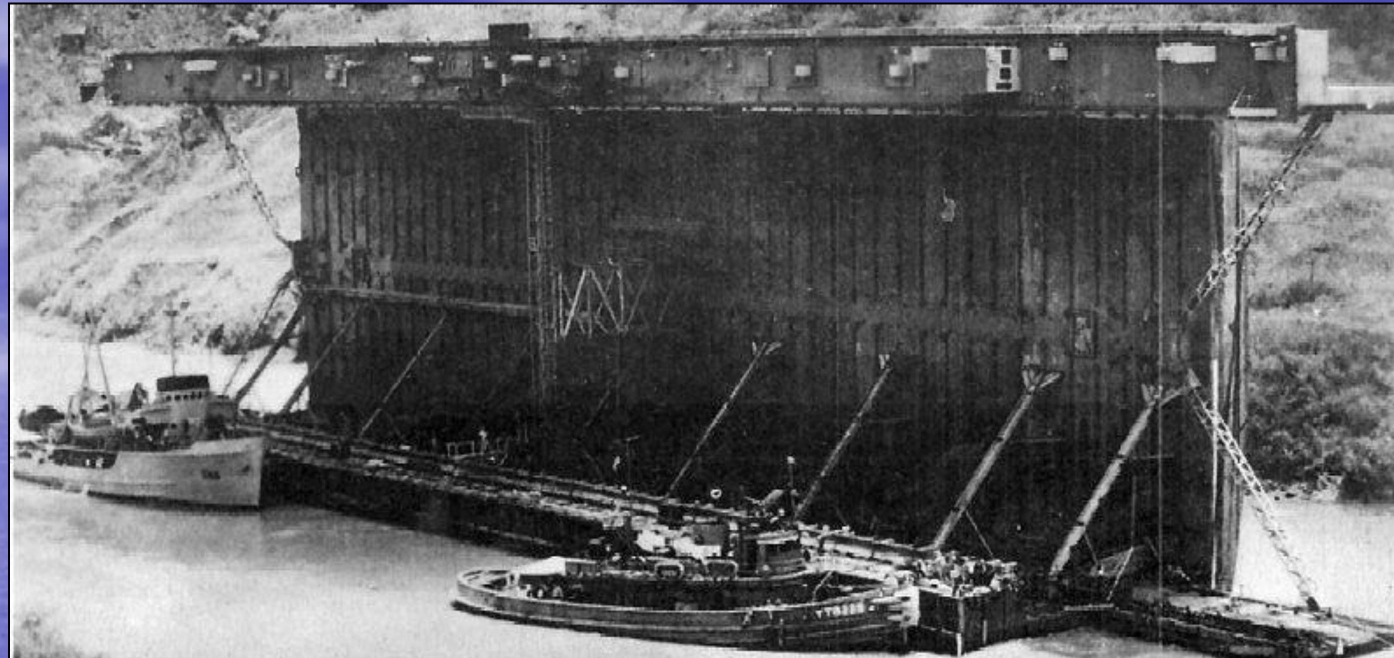
Capital ship design between 1914-42 was controlled by the 110 ft width of the canal's six locks

USS New Jersey in the Pedro Miguel Locks in 1944



The carrier USS Lexington transiting the canal in 1929

The standard Type 6 steel pontoon boxes were 5 ft x 7 ft x 5 ft.

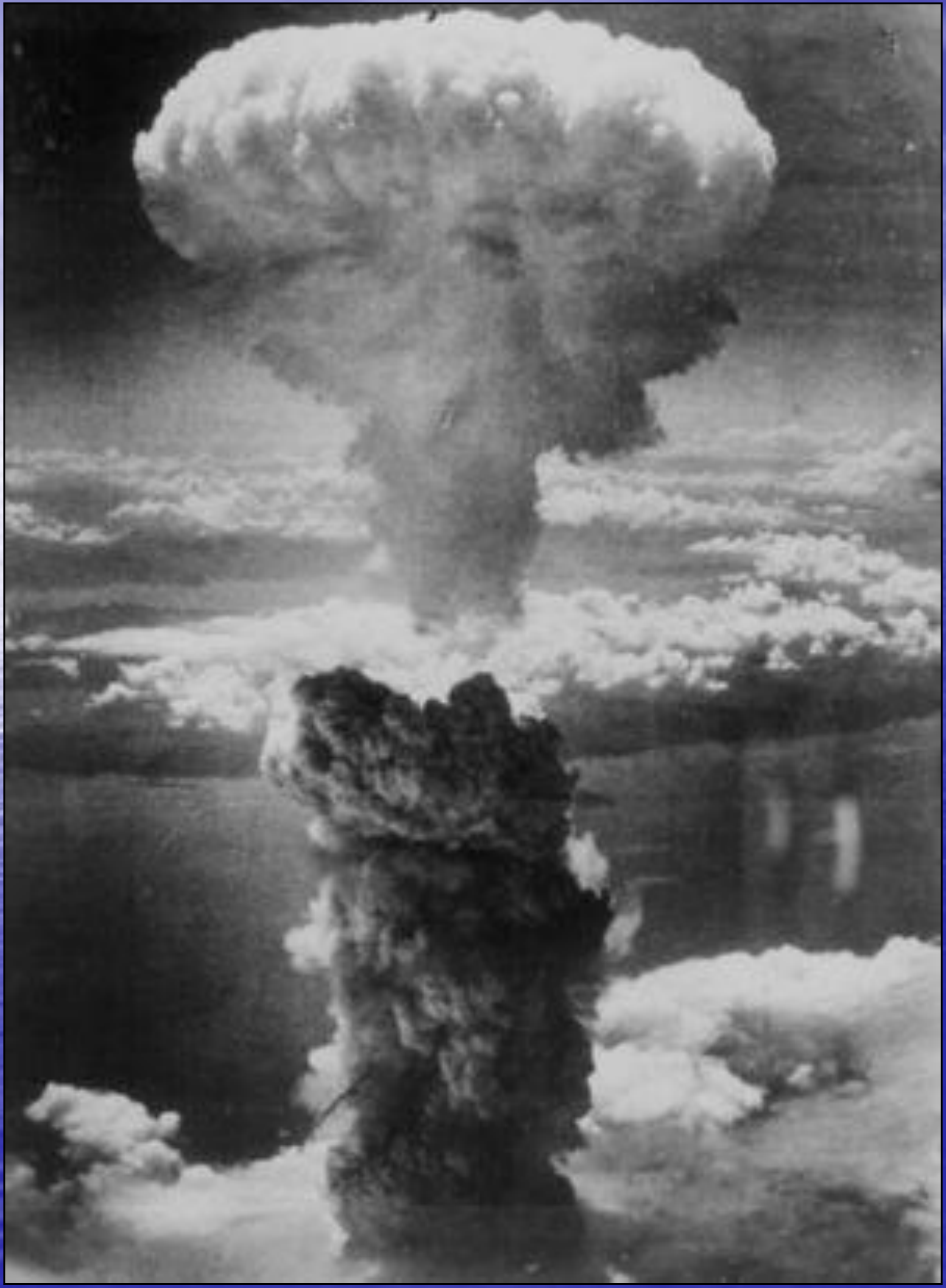


"Pontoon strings" were fabricated by employing steel angle stiffeners along each corner.

- **Navy Seabees added 1000 Type 6 steel pontoons to the edges of Floating Drydock YFD-6 and turned it sideways to transit the Panama Canal in May 1945.**
- **For security reasons, photography of transiting ships was strictly forbidden during the Second World War.**

- **The 40,000 ton Essex Class fleet carriers were the last specifically designed to pass safely through the Panama Canal, by folding up their deck-edge elevator on their port side. But, no one considered the canal's light posts. When the USS Essex made the first canal transit in April 1943, her outboard gun sponsons slashed down every light pole along either side of all six locks!**

- American fleet carriers built after 1945 were too wide to transit the canal, but it was assumed that the canal's locks would be enlarged to accommodate them



Impacts of the Atomic Age

- The bombing of Hiroshima and Nagasaki in August 1945 shattered conventional concepts of protecting critical engineering facilities, like the Panama Canal locks.
- Key issues were *future capacity* and *security*

The Comprehensive Engineering Studies of 1945-48

On December 28, 1945 Congress passed Public Law 280, setting aside $5 million to prepare a comprehensive engineering study to determine whether the Panama Canal could be made safe for merchant or naval fleets during wartime, and ascertain its adequacy to meet the growing demands of peacetime shipping.

Panama Canal Transits 1914-48

The 1947 study estimated that the original canal would be adequate until 1964

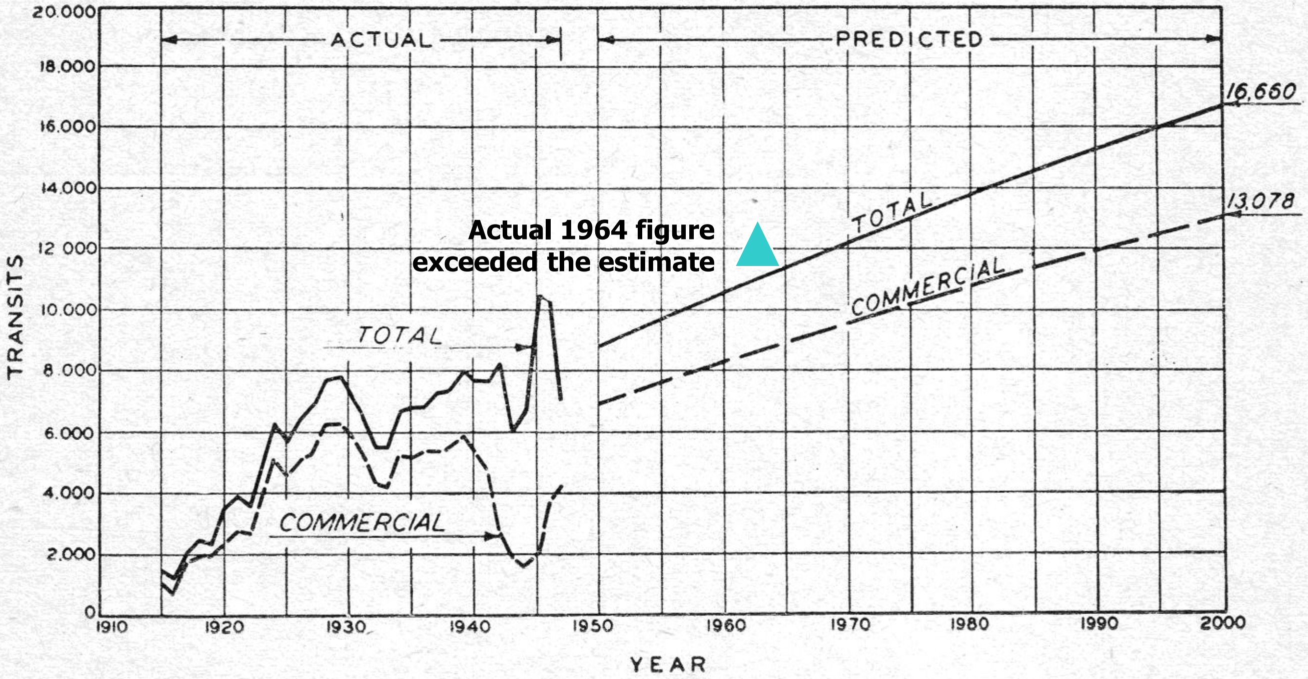


FIG. 3.—PANAMA CANAL TRANSITS

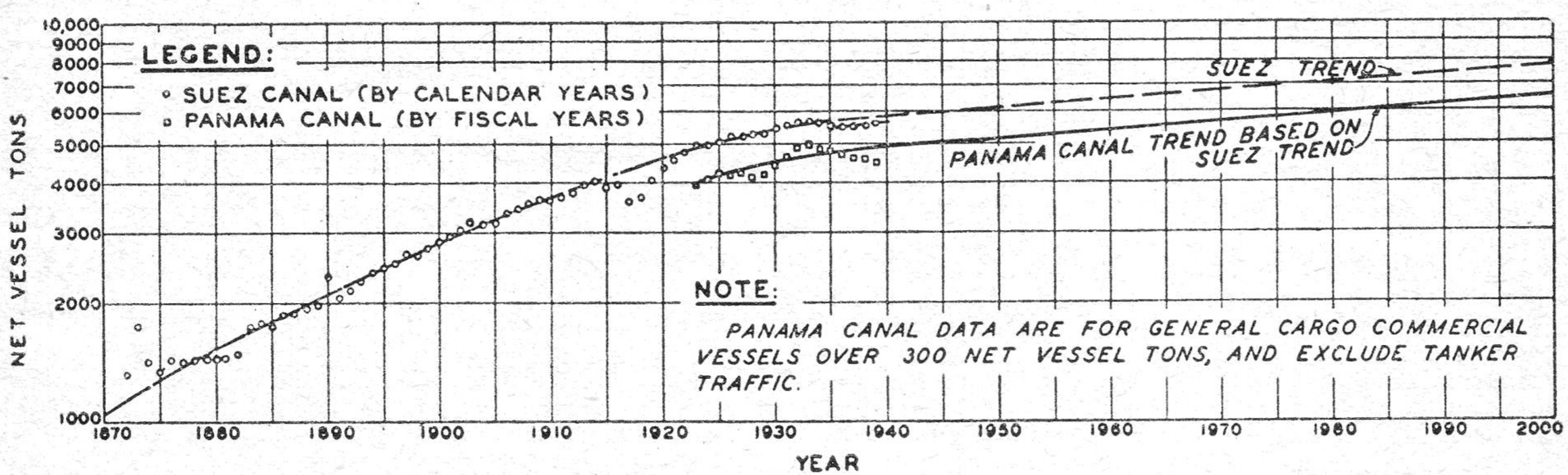


FIG. 12.—AVERAGE NET VESSEL TONNAGES OF GENERAL CARGO SHIPS

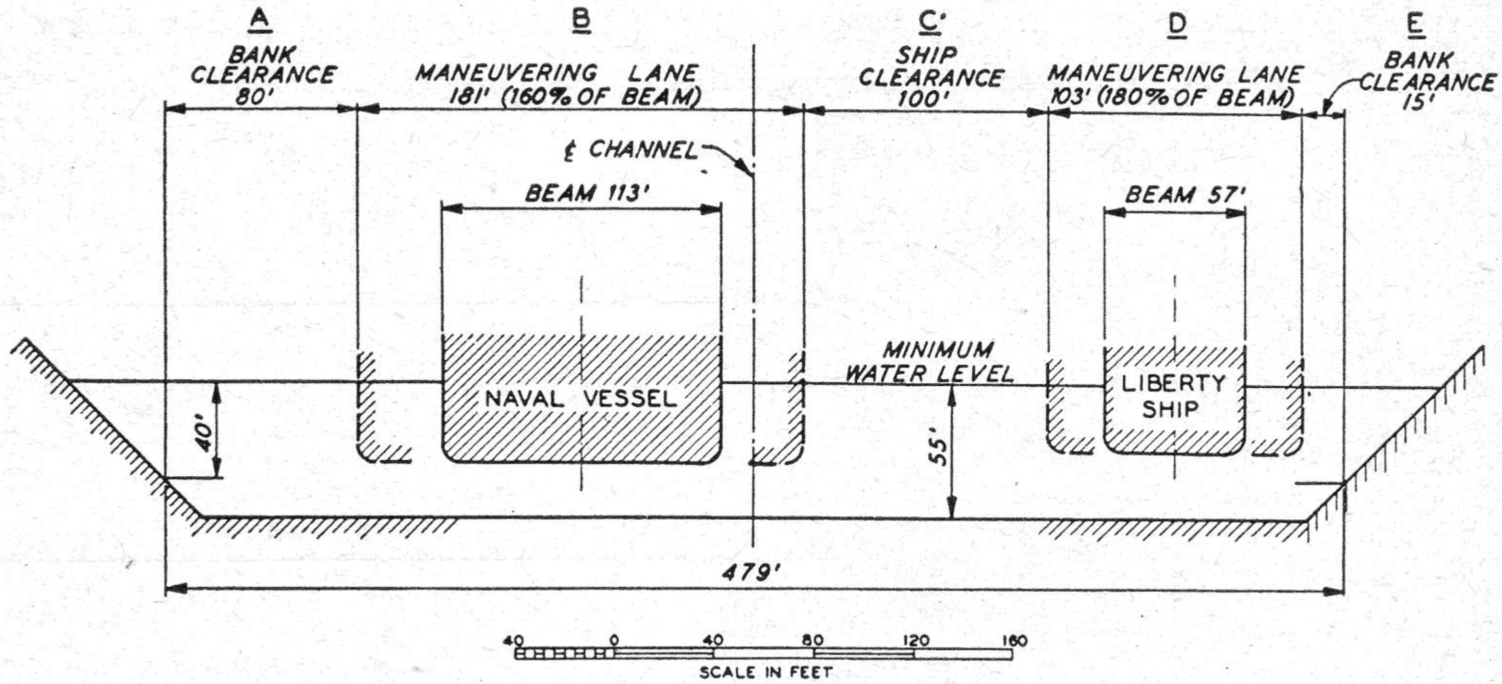


Fig. 60.—Elements of Channel Design; Lock Canal

One-way traffic was common during World War II

- **During the high op tempo of the Second World War hull clearance tolerances were noted by the canal's pilots which proved useful in postwar assessments.**

Maintenance Issues

- The massive steel lock gates of the Panama Canal had to be removed and overhauled to battle corrosion
- This maintenance necessitated the loss of one lock for 4 months every two years, hindering ship transits

The Sea Level Canal Schemes of 1945-48

22 routes were examined in detail; four were selected for detailed examination

The Tehauntepic Canal required 6.5 billion yds^3 of excavation and 15 lifts

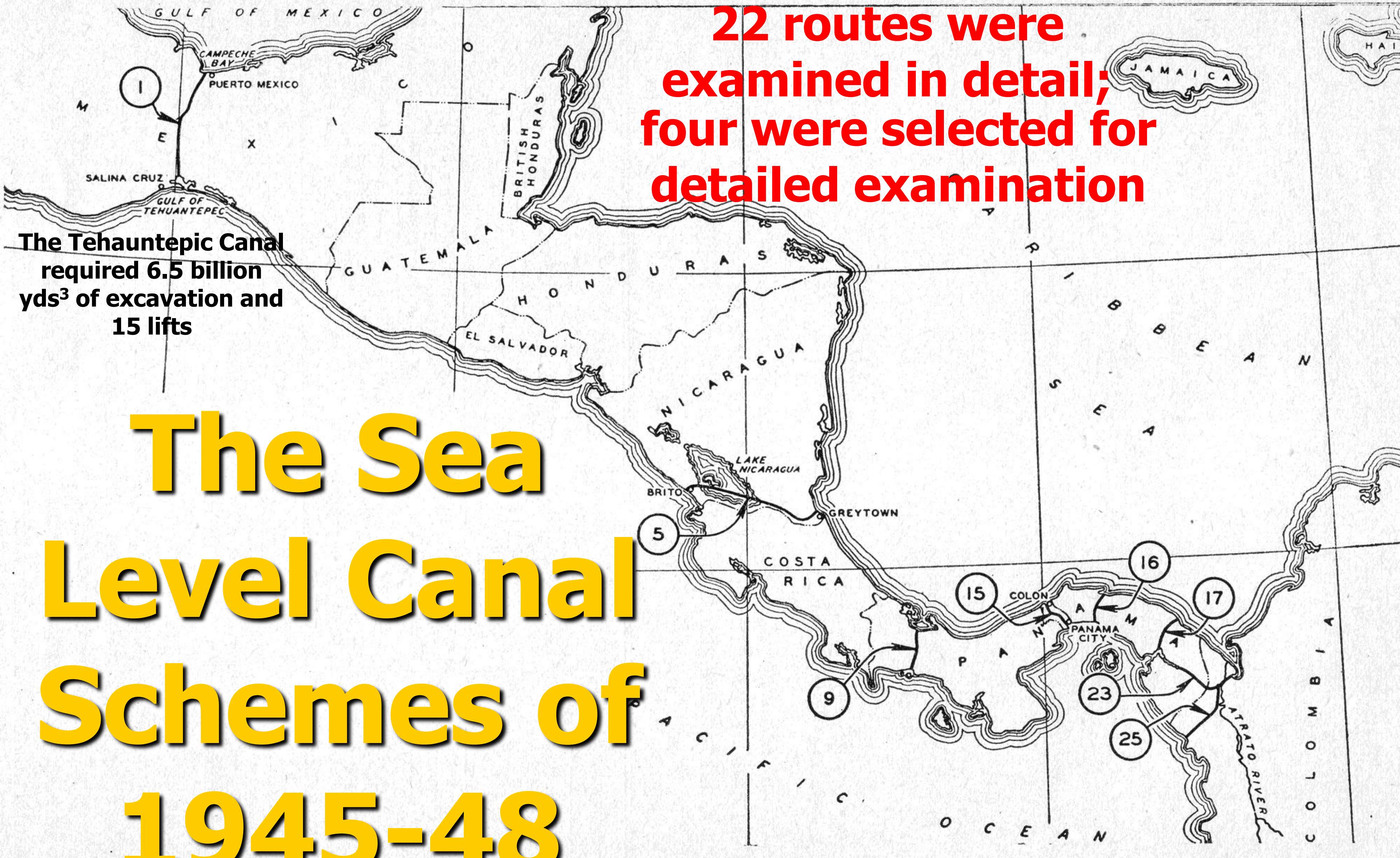
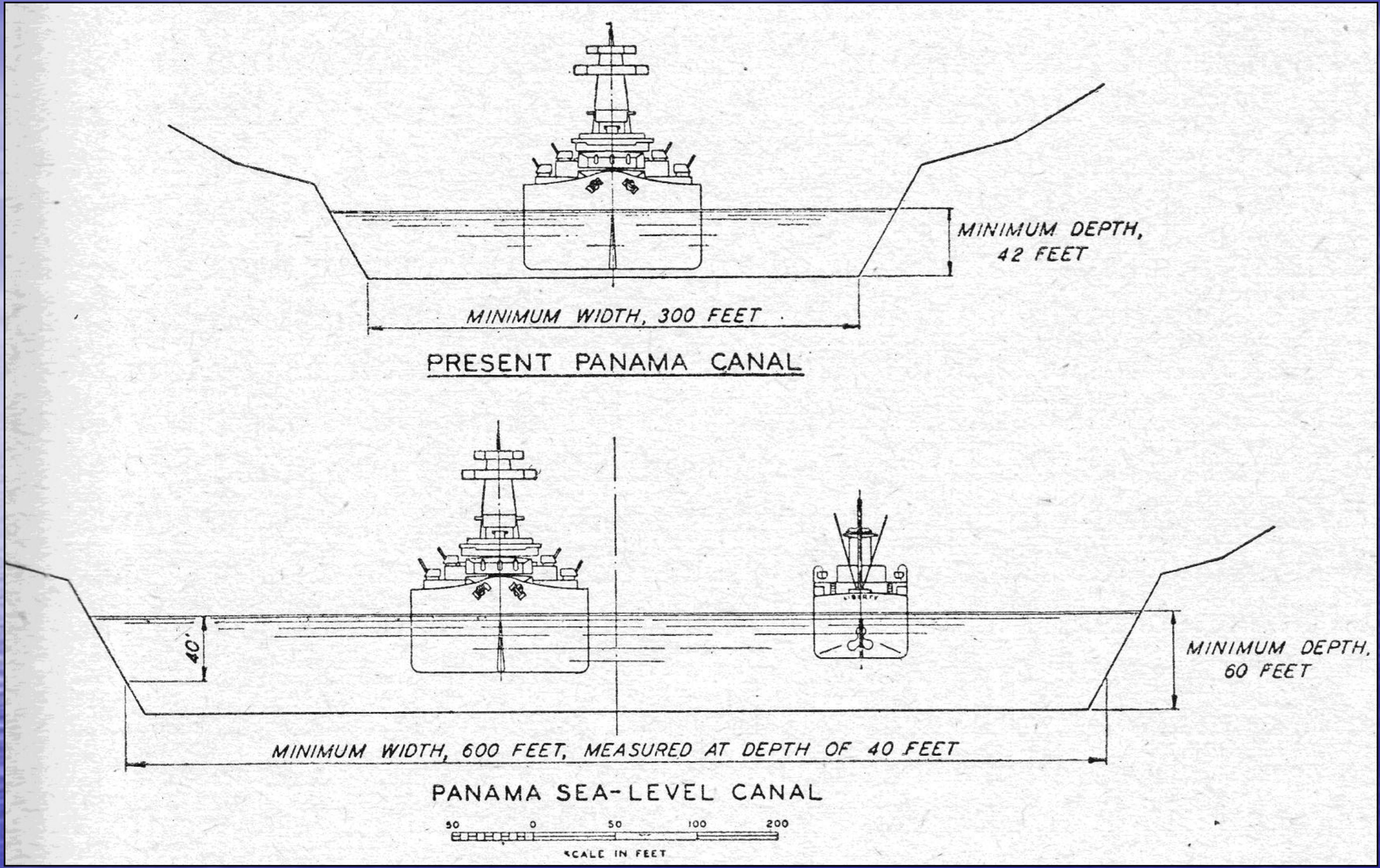


FIG. 6.—TRANSISTHMIAN CANAL ROUTES



- **1946: A sea level canal would allow two-way traffic without costly delays at either end, required to pass through locks**
- **The sea level canal would have been 600 ft wide and 60 ft deep, requiring excavations up to 60 ft deep on the Atlantic side and up to 70 ft deep on the Pacific side**

Panama Sea Level Canal Plan of 1948

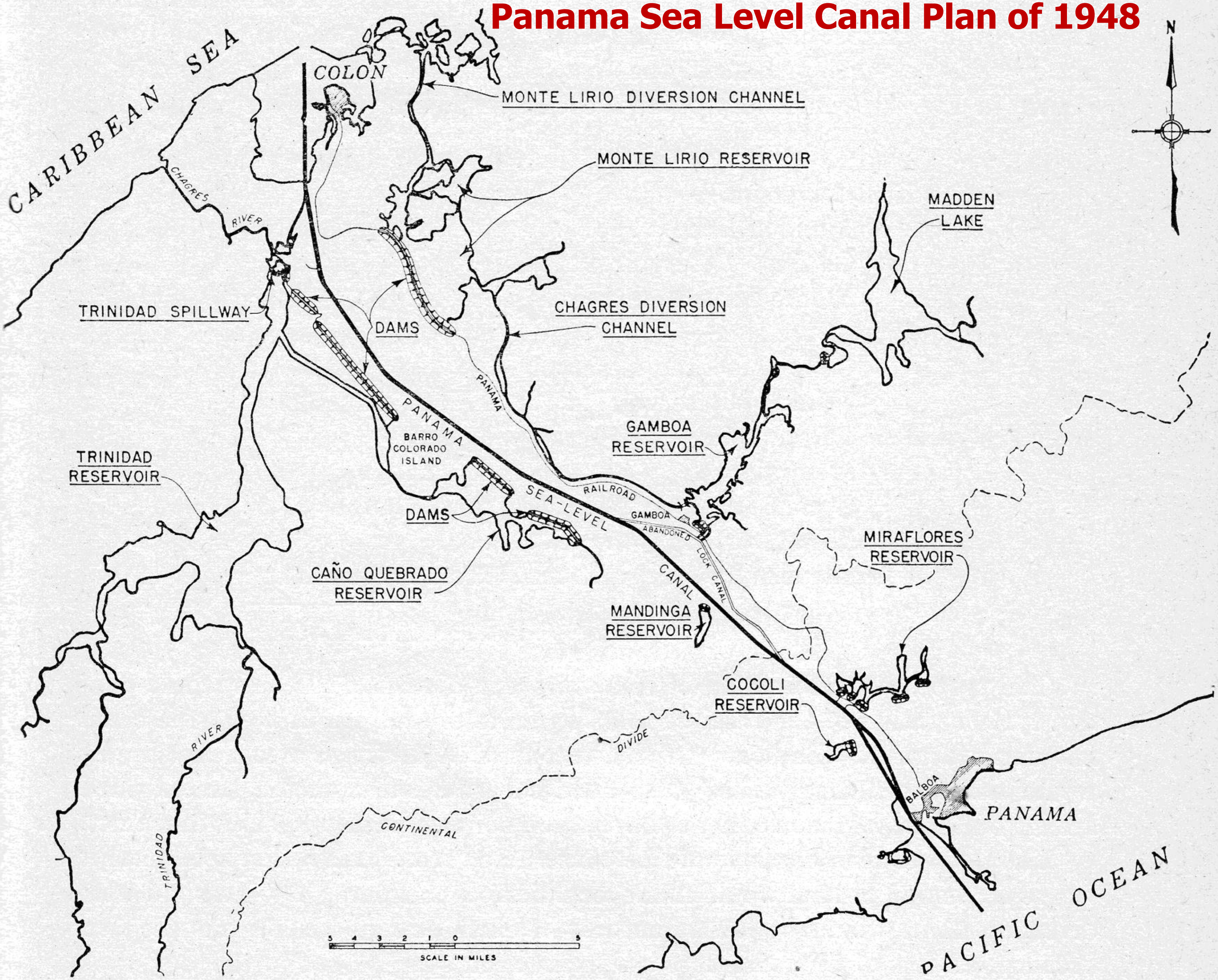
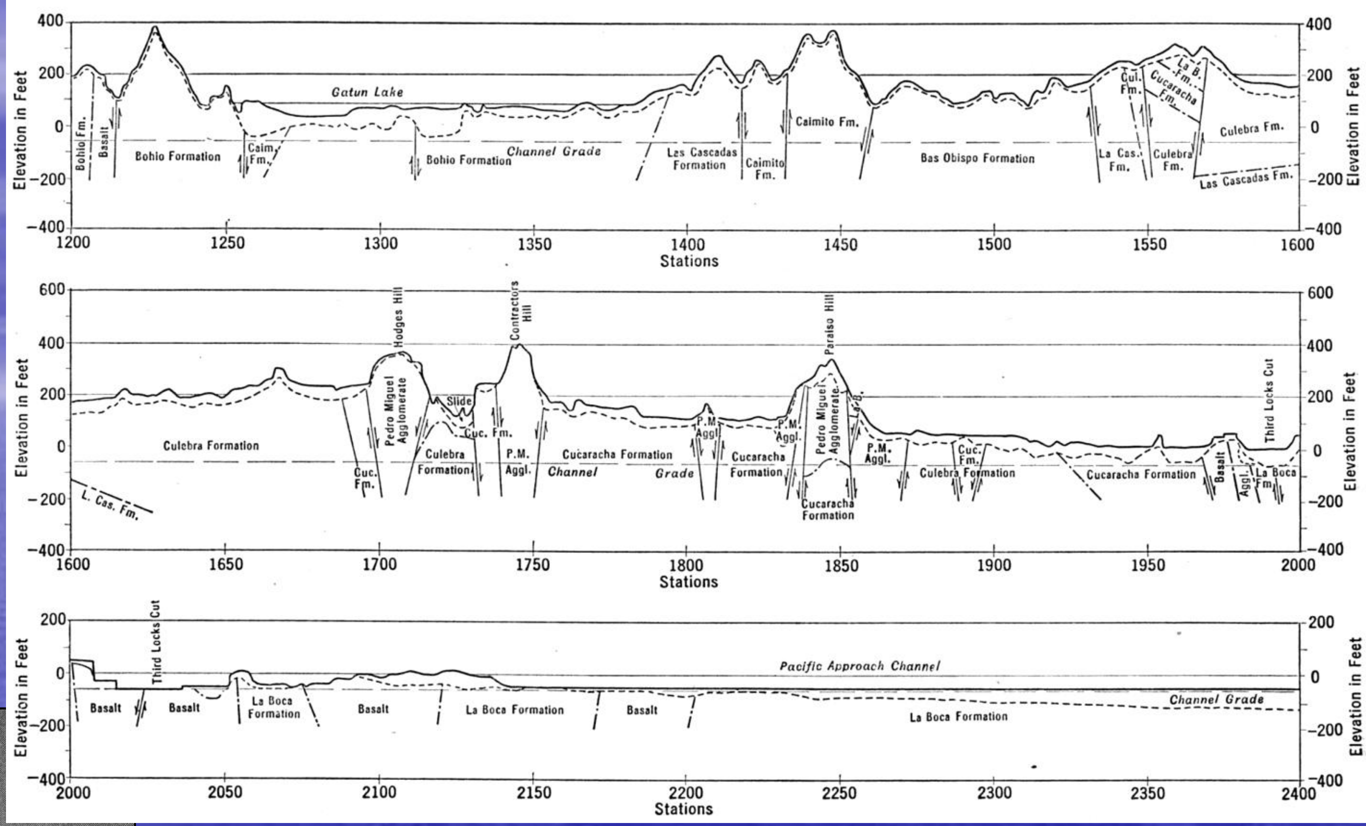
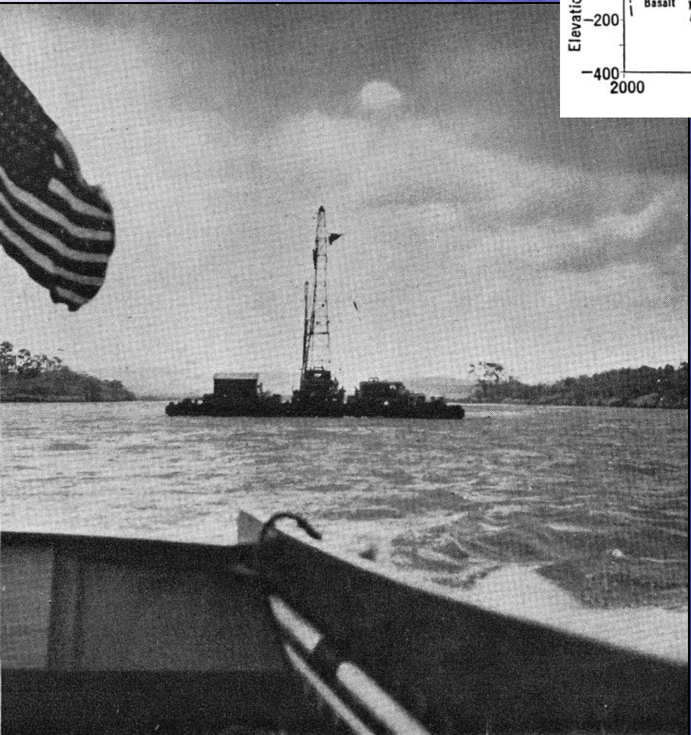


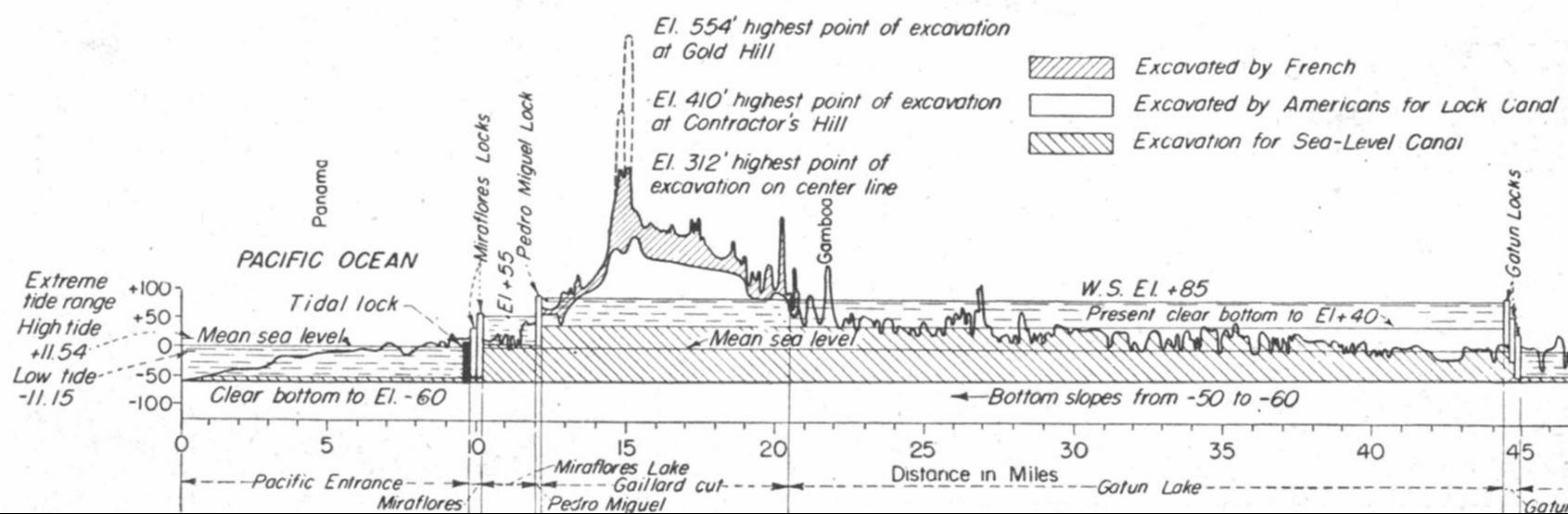
FIG. 11.—SEA-LEVEL CANAL FLOOD CONTROL SYSTEM.

Post-war engineering geology work





- The post-war feasibility studies by the Army Corps of Engineers recognized the enormous influence of geology on construction and excavation costs
- They developed techniques of drilling exploratory borings in up to 135 feet of water from barges, such as that shown here.



- **Profile of the Panama Canal** illustrating the excavations made by the French, by the Americans, and what would be required in 1948 to excavate a sea level canal.
- The biggest challenge was the requirement to excavate between depths of -85 ft (across most of Gatun Lake) to as much as -135 feet below the existing water surface in the Culebra Cut.

Dredge Development Contracts

Temporary conversion locks could be discarded if dredges capable of excavating to depths of -135 feet could be developed.

20 to 30 yd³ dipper dredge

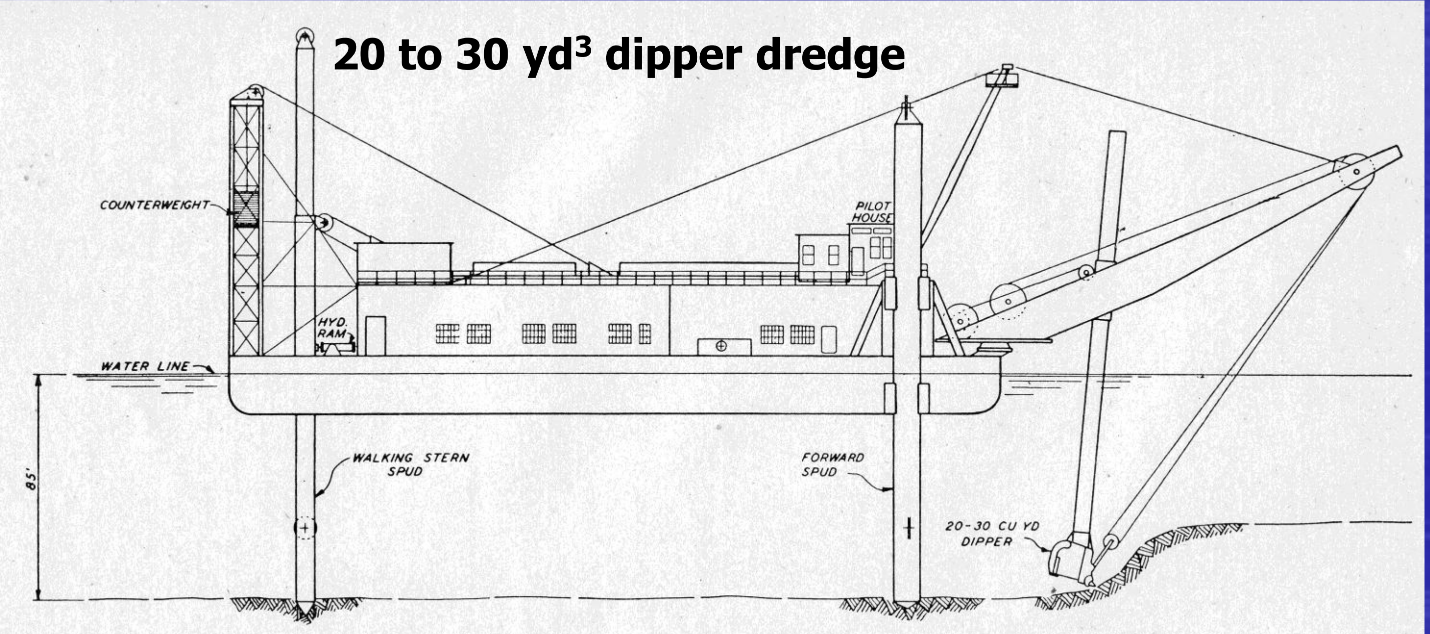


Fig. 102.—Proposed 20-Cu-Yd to 30-Cu-Yd Dipper Dredge

The dipper dredge would need a bucket capacity of 20 to 30 yds^3. The spuds on this machine would be 150 ft long, with telescoping legs 80 ft long, and a 165 ton counter-weight. Estimated cost was \$5 million

Dredge Design Concepts

Hydraulic dredge

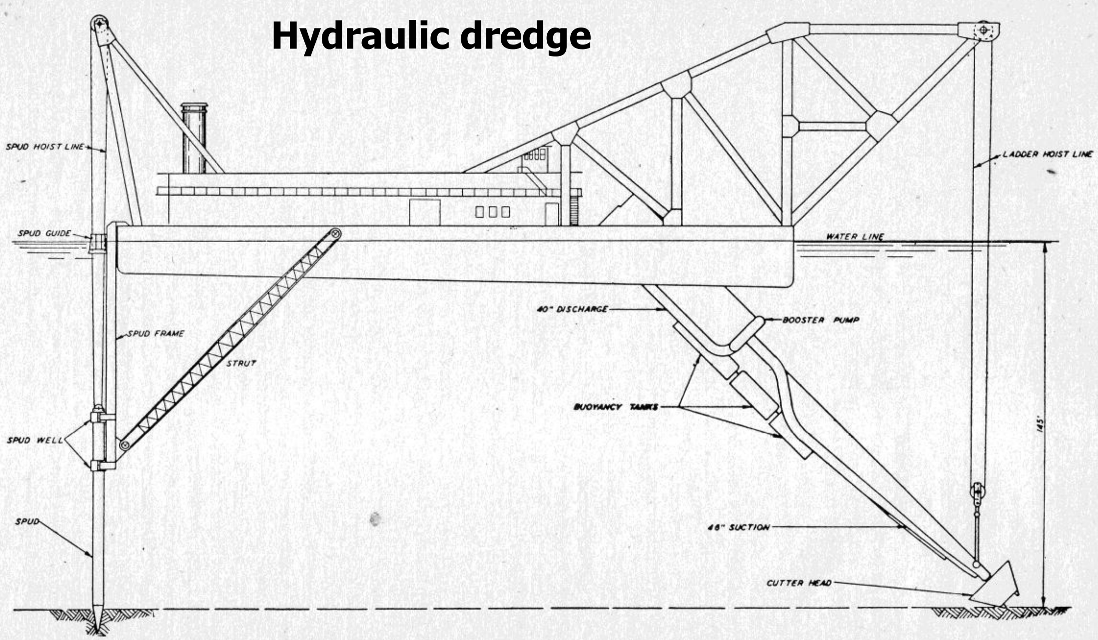


Fig. 100.—Proposed 40-In. Hydraulic Dredge

The hydraulic dredges would require 46 inch diameter suction and 40-inch discharge lines, with booster pumps set 65 ft below water level, on a 185 ft long boom

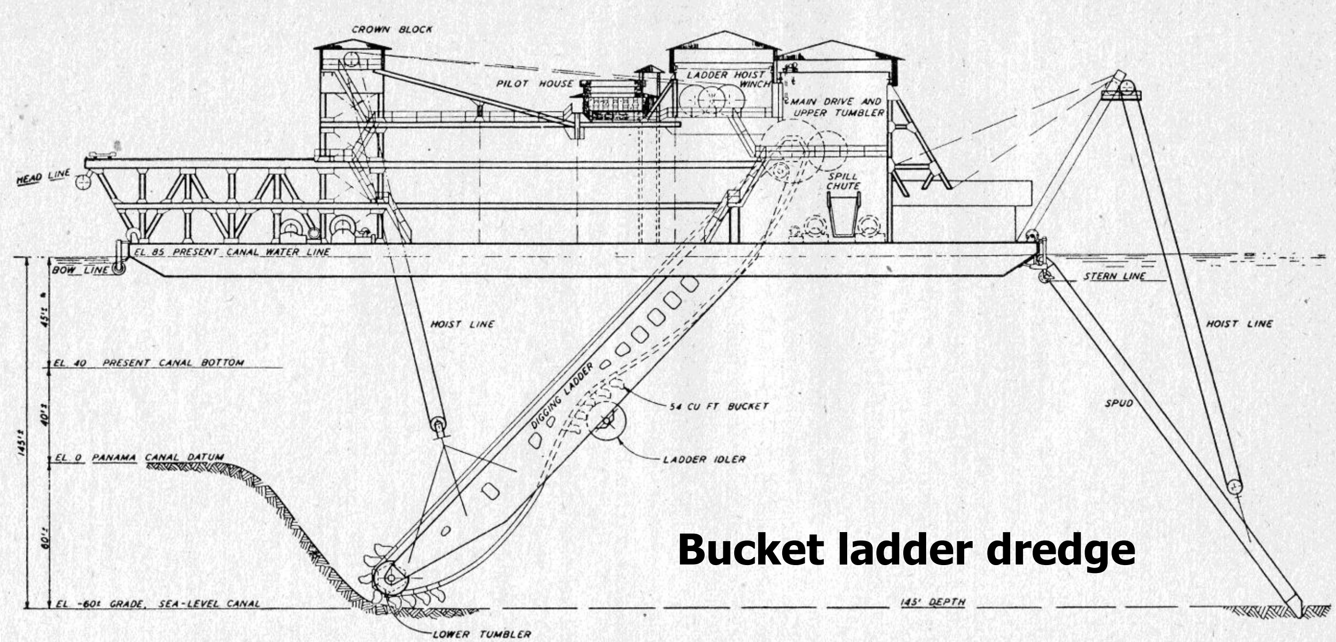
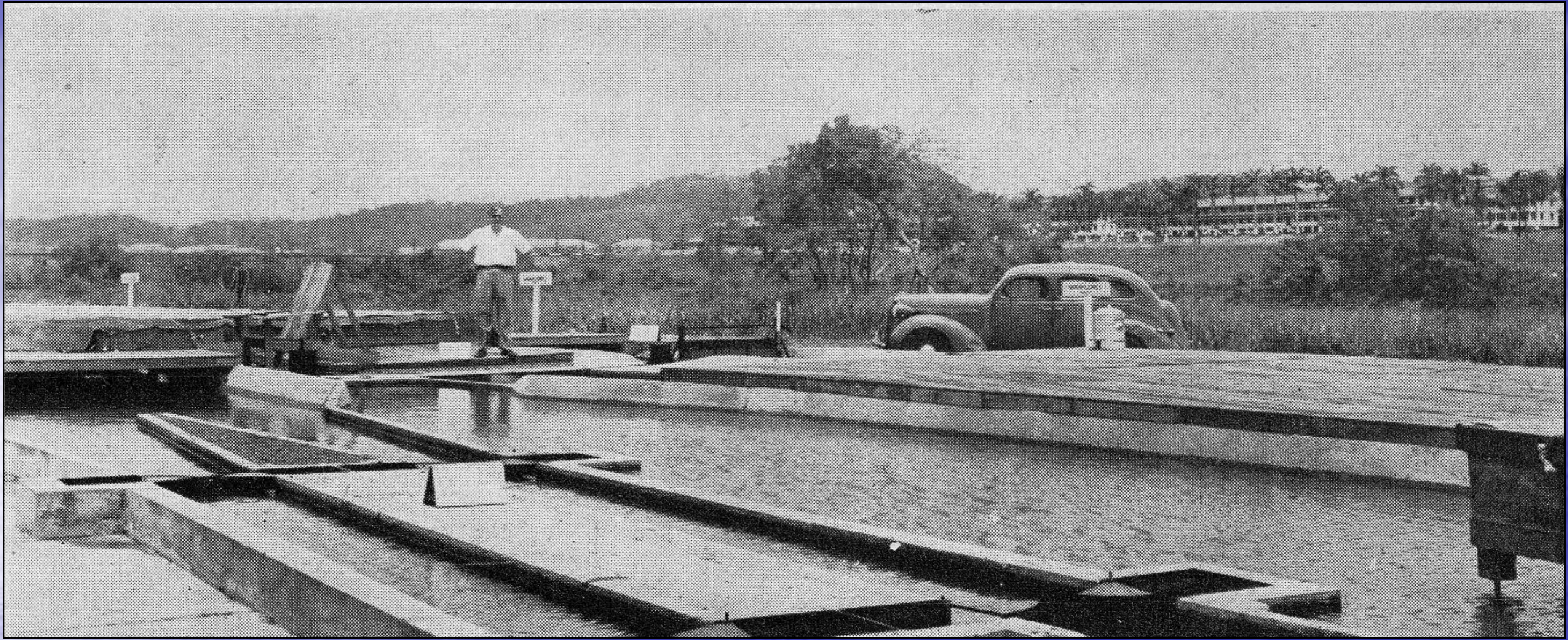
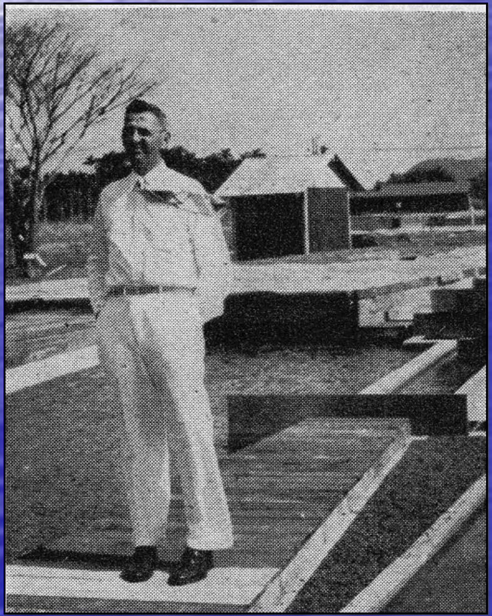


Fig. 101.—Proposed 54-Cu-Ft Bucket-Ladder Dredge

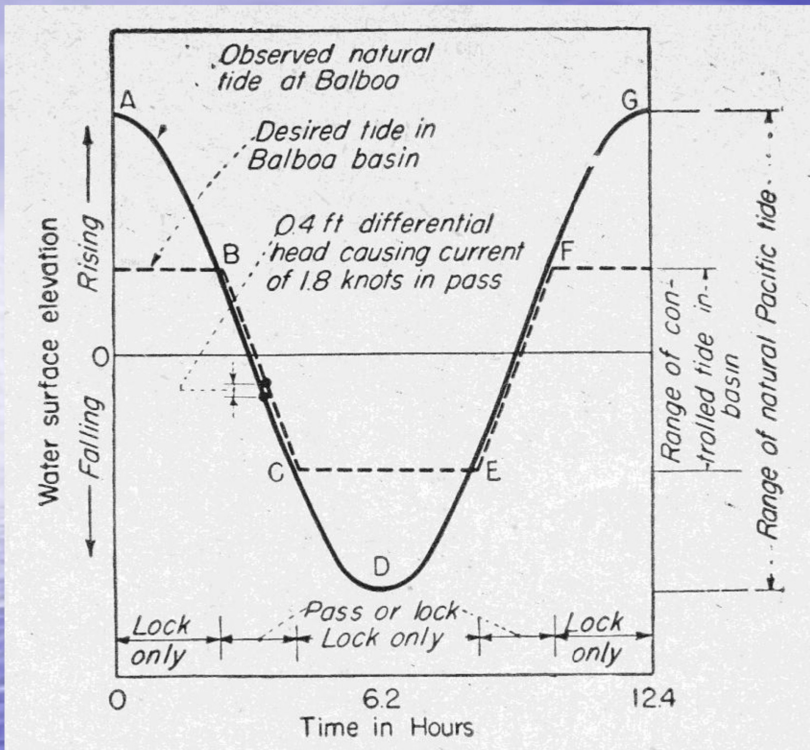
The bucket ladder dredges would have employed 2 yd^3 buckets capable of excavating to depths of -135 ft. The Yuba Manufacturing Co had built 2/3 yd^3 bucket dredges capable of excavating to -124 ft



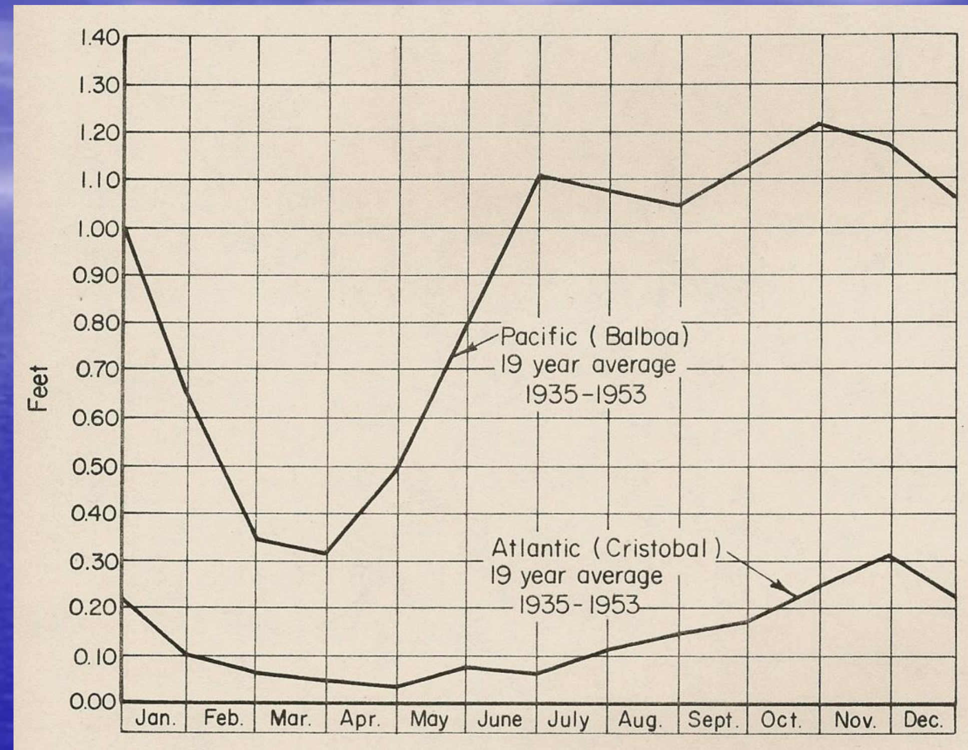


- **Colonel James H. Stratton** (lower left) constructed a half-mile long hydraulic model of the Canal Zone (shown above in 1946) to examine the various facets of tidal influx and flood control on a sea level canal.
- The US Navy favored the **Pacific Terminal Lake Plan,** which relocated the Pedro Miguel Lock to Miraflores, creating an enlarged Miraflores Lake at the same level as Gatun Lake (+85 ft). This idea was conceived by **Navy Captain Miles P. Duval** during the Third Locks Project, between 1939-42.

The Navigable Pass Plan



Tidal throw on the Pacific and Atlantic sides



- **The Corps of Engineers model studies suggested that tidal control structures could be operated to accommodate shipping. Above left: Between B and C, water would flow out of the canal into the ocean through control gates, and between E and F, the flow would be into the canal. During these periods ships could transit the tidal passes.**

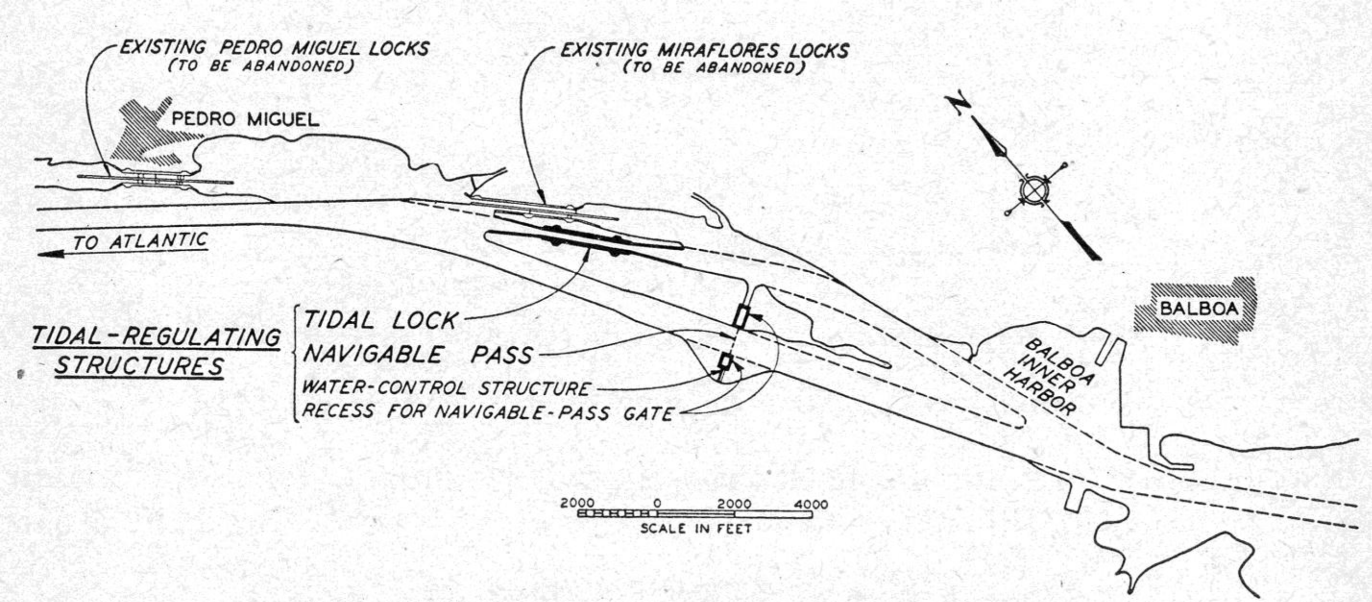
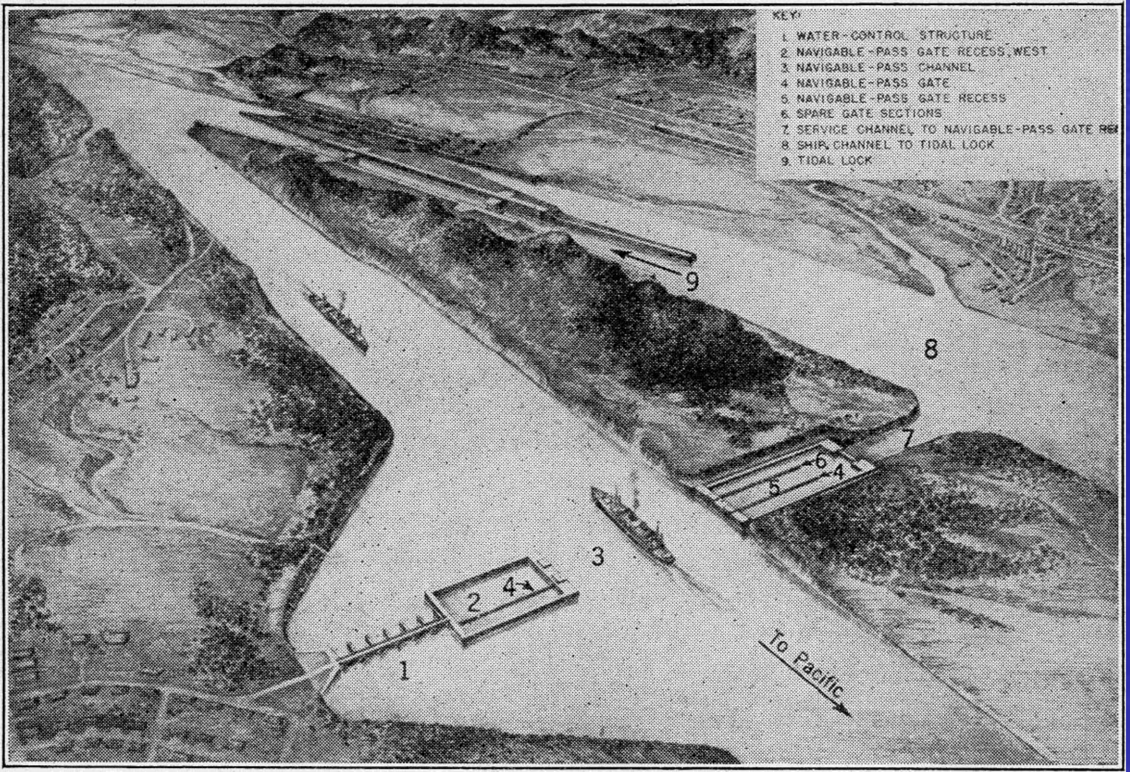


FIG. 37.—LAYOUT OF TIDAL-REGULATING STRUCTURES

Tidal regulation structures

The tides are 20 ft on the Pacific side and 2 ft on the Atlantic side



- One of the significant engineering challenges of a sea level canal was how to handle the 4.2 knot currents triggered by the 20-ft tides on the Pacific side of the Canal, too high for safe ship transits.

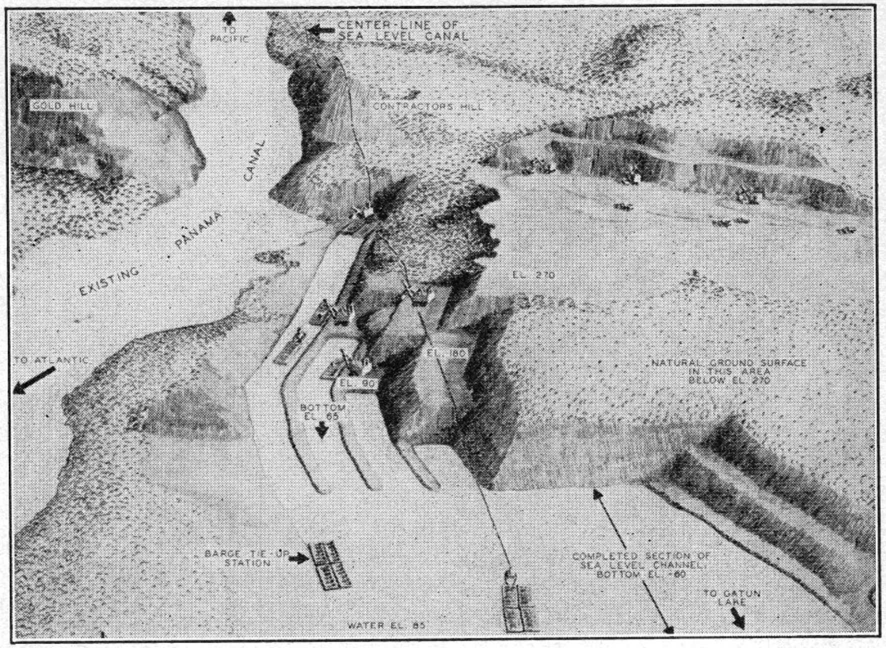


FIG. 98.—EXCAVATION ABOVE EL. 90, APPROACHING CONTRACTORS HILL FROM THE NORTH

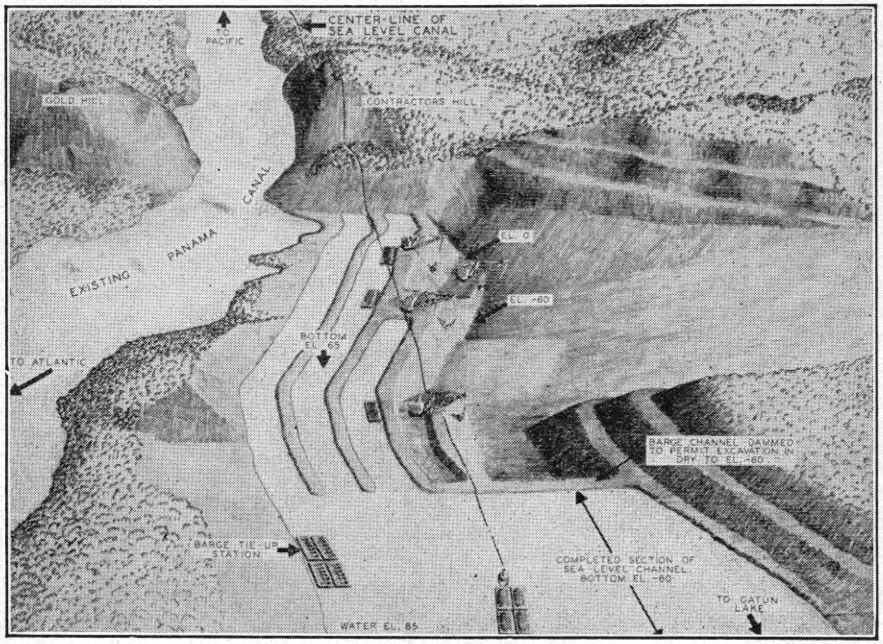
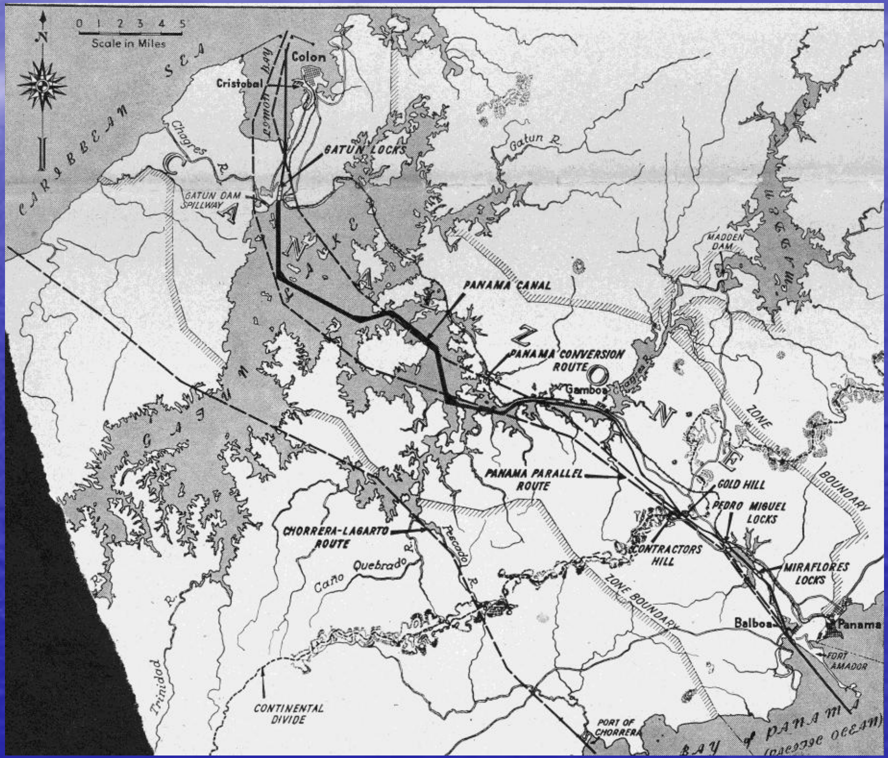


FIG. 99.—EXCAVATION BELOW EL. 90, APPROACHING CONTRACTORS HILL FROM THE NORTH

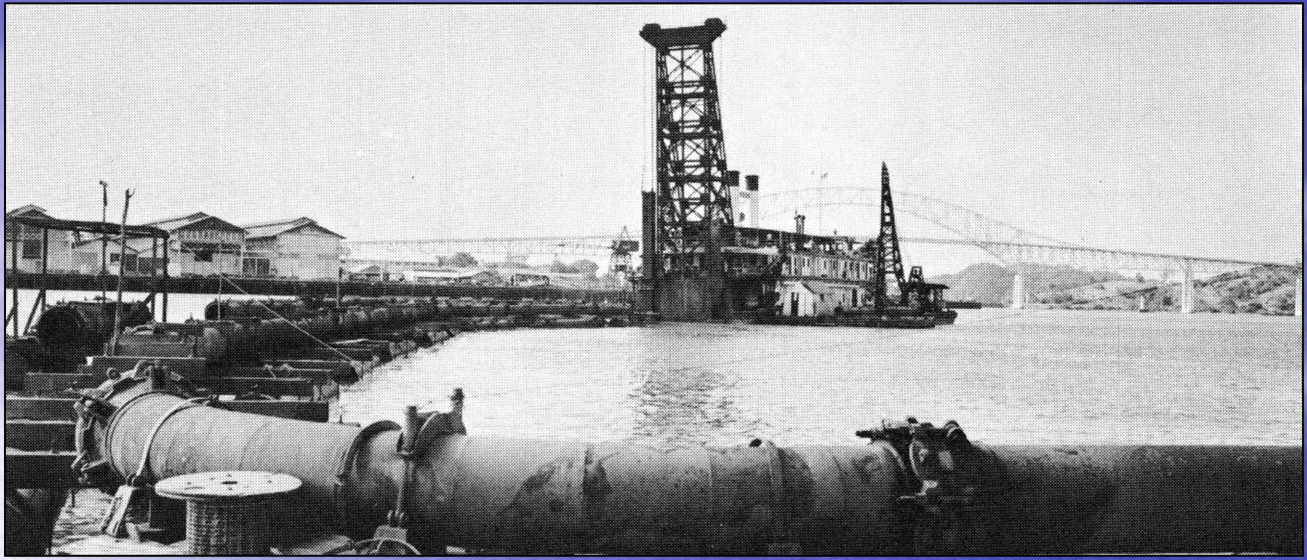
Significant Excavations



- The **sea level canal scheme** of the late 1940s envisioned about 1.07 billion yds³ of excavation, of which 750 million yds³ would have been excavated in the dry, with dredging removing the remaining 320 million yds³

The Canal Widening & Lighting Projects of the 1960s

By the early 1960s the Canal was averaging 12,000 transits per year. The $20 Million Thatcher Ferry Bridge linked the two Americas in 1962. It has since come to be known as the "Bridge of the Americas."



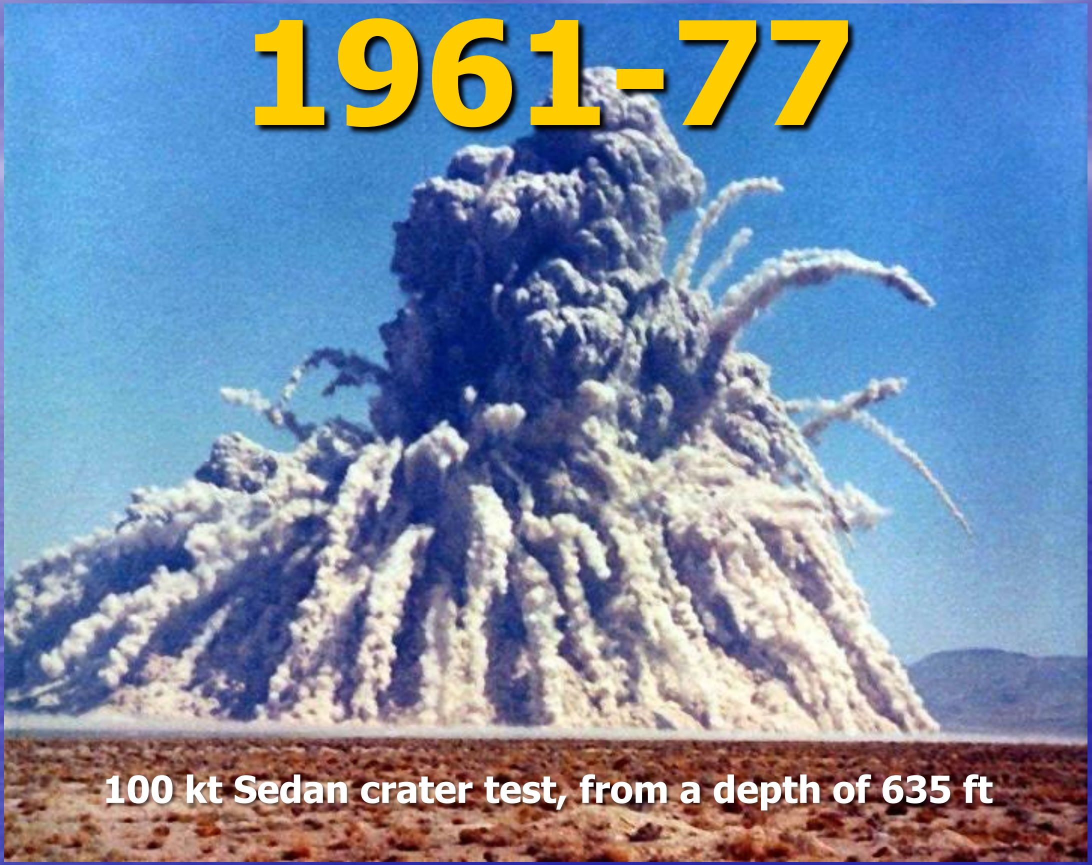
Dredging is carried out to maintain the approach channels on either end of the canal

- Between 1962-70 the Galliard Cut was widened from 300 to 500 feet, by excavating 22 million yds^3
- Lights and navigation aids (radar reflectors) were also installed in the cuts, locks, and approaches to allow nighttime transits.

Navigation Improvements

- The widening of the canal to 500 ft was carried out between 1962-70.
- The Panama Canal Commission also installed lights and pilot navigation aids, to allowed two way traffic in the widest portions of the canal and 24-hr per day transit, under favorable weather (no fog)

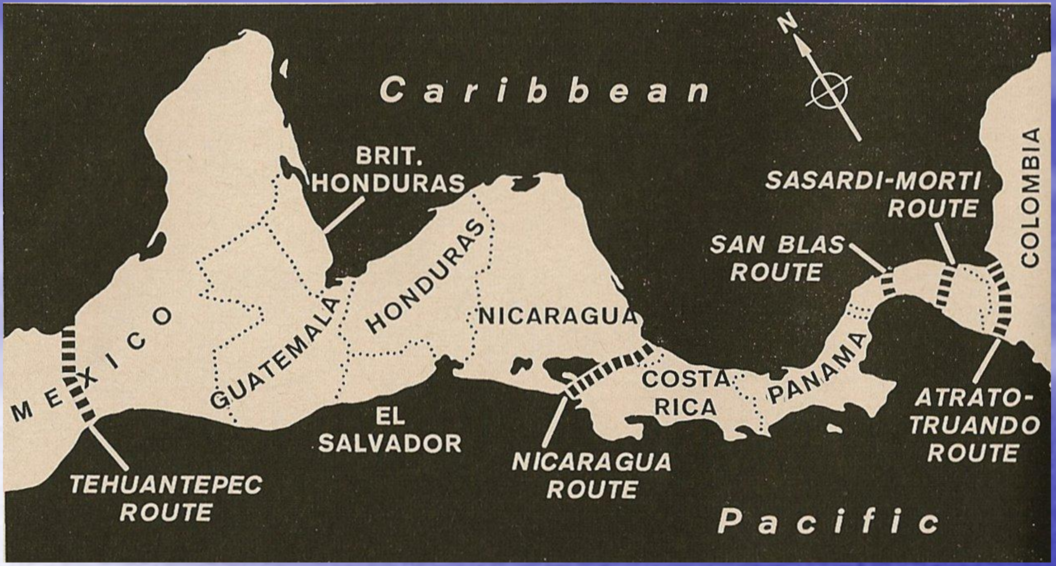
Operation Plowshare 1961-77

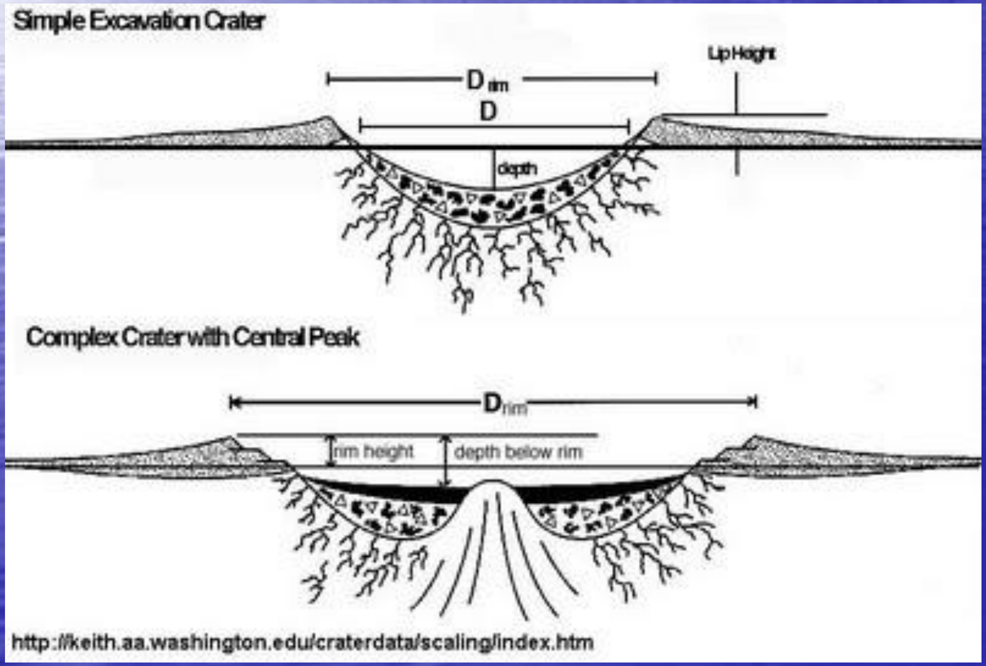


100 kt Sedan crater test, from a depth of 635 ft

The PLOWSHARE program conducted six cratering nuclear explosions which contributed information for feasibility studies examining the widening of the Panama Canal or excavating a new canal through Nicaragua using nuclear detonations

The "Pan-Atomic Canal" routes

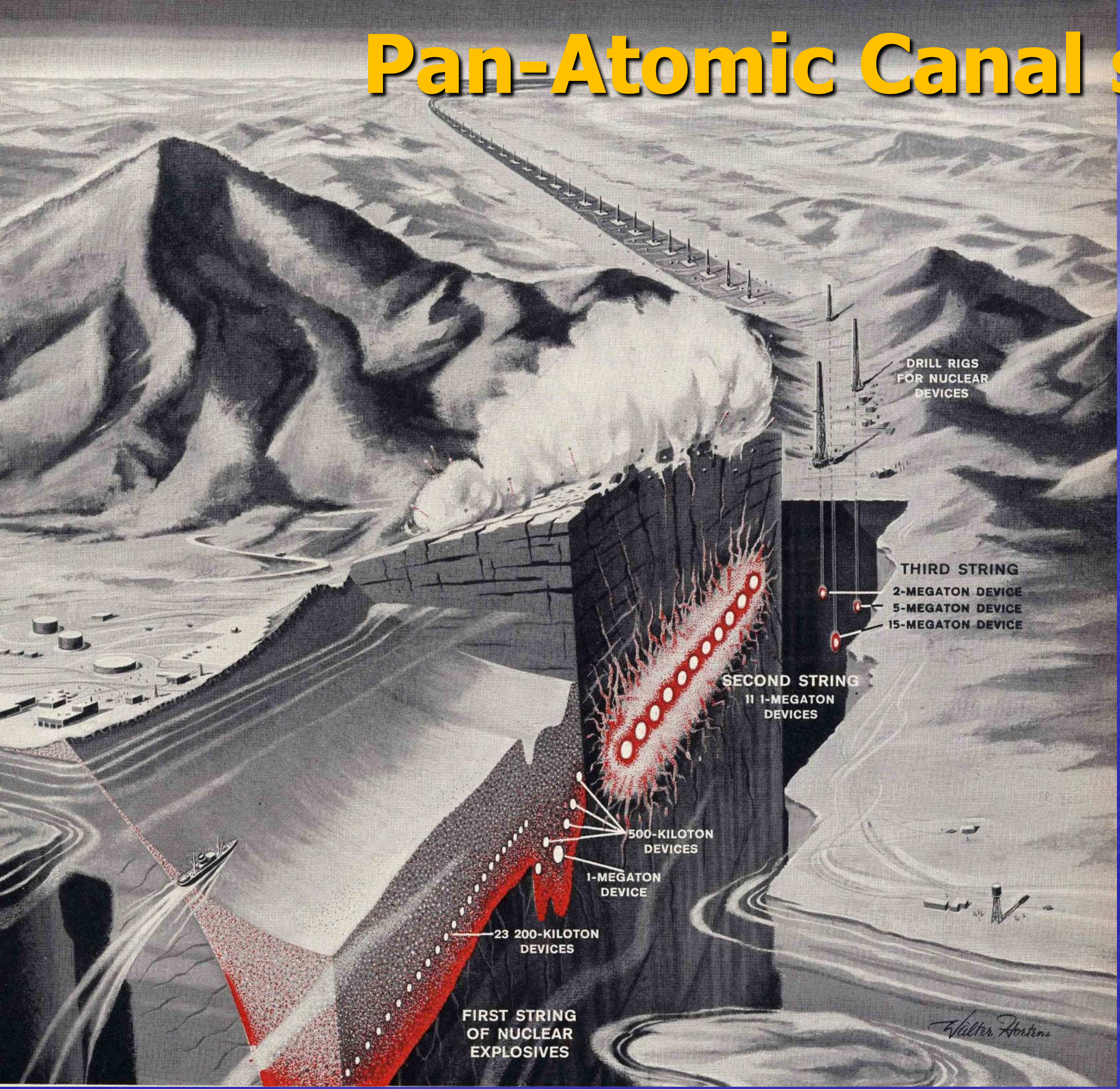




Projects Gnome and Sedan were a series of underground detonations at Nevada Test Site in 1961-64 that succeeded in excavating craters of up to 2.4 million yds^3

- Over the next 11 years 26 more nuclear explosion tests were conducted under the U.S. PNE program. Funding quietly ended in 1977. Costs for the program have been estimated at more than $770 million.

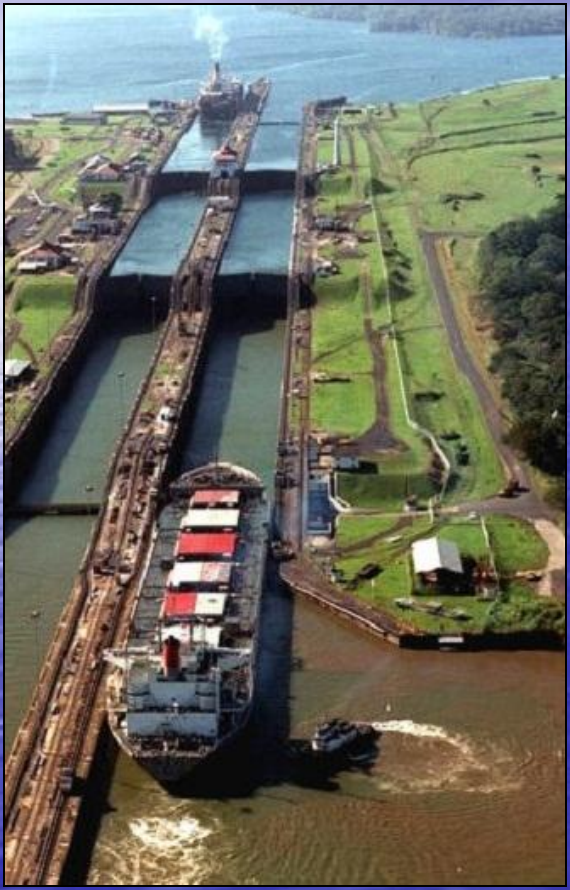
Pan-Atomic Canal scheme



The Plowshare scheme envisioned a string of 2, 5, and 15 megaton devices detonated at varying depths, to "throw" the spoils aside.

This shows the detonation of the bedrock "plug" section adjacent to the sea level approach (from LIFE magazine March 6, 1964)

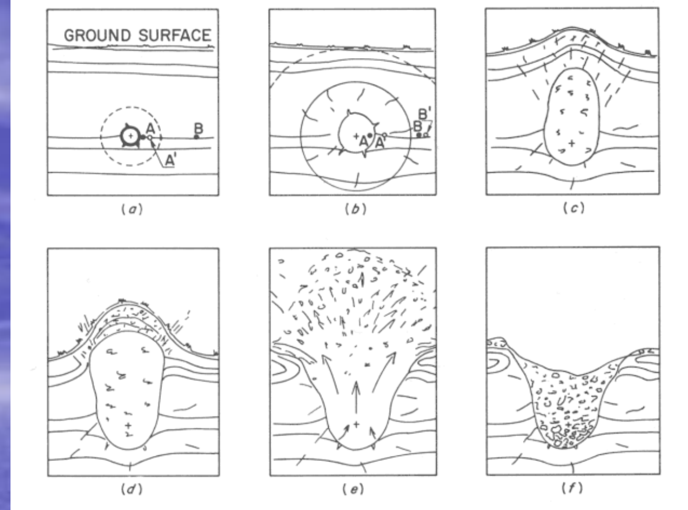
Atlantic-Pacific Interoceanic Canal Study Commission 1965-70



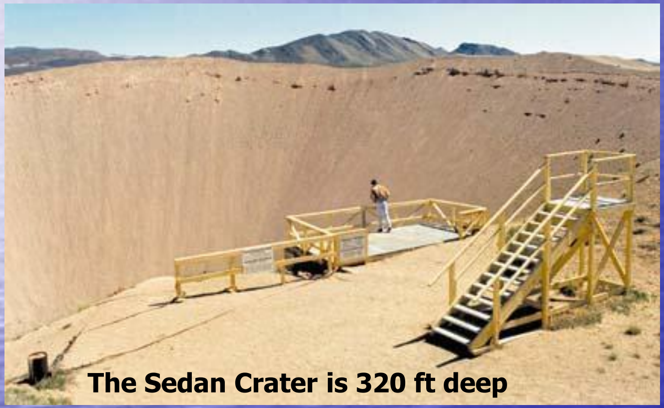
During 1964 Congressional hearings experts from the Army Corps of Engineers and Atomic Energy Commission testified that the cost of excavating a new sea-level canal could range anywhere from $620 million for a canal through San Blas, Panama, excavated by nuclear methods, to as much as $13 billion for one at Tehuantepec, Mexico, using conventional excavation procedures.

According to the Atomic Energy Commission, the nuclear approach probably could not be used under the recently approved nuclear test ban treaty limitations.

As a consequence of these conflicting estimates, Congress passed Public Law 88-609 on September 22, 1964.

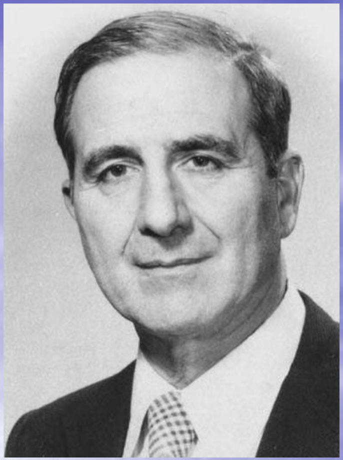


- A non-partisan **Atlantic-Pacific Interoceanic Canal Study Commission** was appointed by President Lyndon Johnson in April 1965 *"to make a full and complete investigation and study…. For the purposes of determining the feasibility of, and most suitable site for, the construction of a se-level canal connecting the Atlantic and Pacific Oceans; the best means of constructing such a canal, whether by conventional or nuclear excavation, and the estimated cost thereof."*
- The US Army Corps of Engineers employed 50 geologists to assess potential routes in 1967 and '68.
- They chose Route 8 (nuclear) in Nicaragua, Routes 10 and 14 in Panama, Route 17 (nuclear) in Panama, and Route 25 (nuclear) in Columbia for detailed study.
- They concluded that a sea level canal would require between 1.5 and 2.0 billion yds^3 of excavation



- Upper Left: In March 1968 the AEC oversaw the Project Buggy test , the first nuclear row charge experiment . The explosion, which involved the simultaneous detonation of five explosives (each detonation yielded 1.08 kilotons) placed 150 feet apart at a depth of 135 feet created a ditch 855 feet long, 254 feet wide, and 65 feet deep.
- Evaluation of the nuclear aspects of the study were aided by the Atomic Energy Commission's successful detonation of the 30 to 35-kiloton SCHOONER shot in December 1968 at the Nevada Test Site, which produced a crater approximately 850 feet in diameter and 200 feet deep. This was the last Plowshare canal test.

Conclusion of the Plowshare Program- November 1970

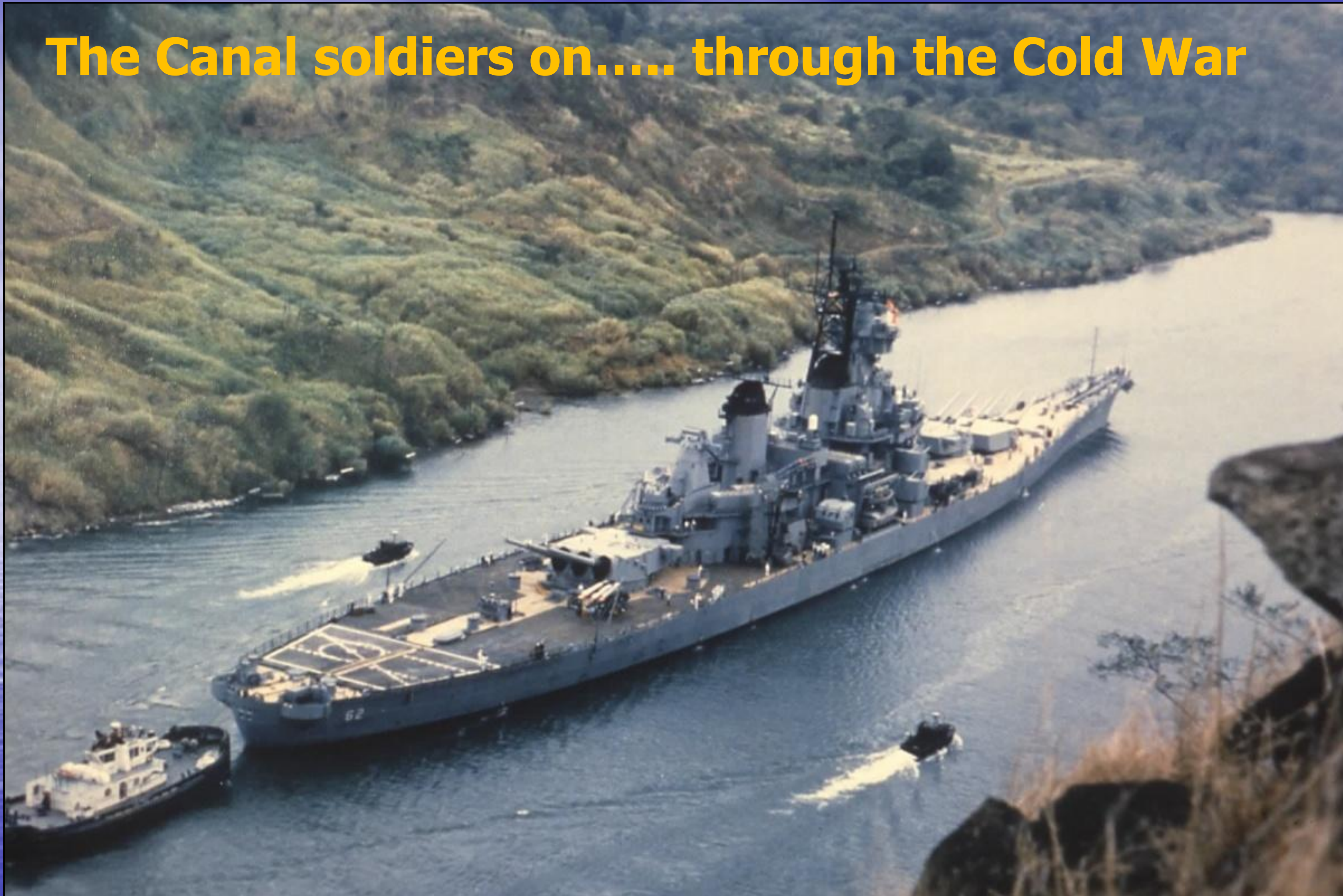


ICS Commission
Chief Engineer
BGEN Charles C. Noble

The feasibility of nuclear excavation was never verified because nuclear cratering tests in the megaton range had been fraught with too many uncertainties.
The nuclear excavation schemes were about $500 million less expensive than conventional excavation schemes, but the all-nuclear routes were not considered feasible because of safety concerns or unsuitable geologic conditions.

- Route 25 in northwestern Colombia (estimated cost of $2 billion) would have been the preferred route. Most of this expense would have been expended for the conventionally excavated portions of that route.
- The AEC believed that it could resolve the major technical uncertainties relating to Route 25, but the STURTEVANT and YAWL shots, intended to complete the Plowshare canal studies, were never conducted, because of increasing concerns about public reaction to the radiation that would have been released.
- Field operations were terminated in July 1969 and engineering feasibility and environmental impact studies were concluded between June and November 1970.
- The Interoceanic Canal Study Commission study submitted in 1970 recommended against employing nuclear excavation technology because of concerns about relocating indigenous populations and possible damage to the environment from radioactivity. They also concluded that a sea-level canal was not economically justifiable.
- Smaller scale Plowshare tests continued through 1977, examining other peaceful uses of nuclear weapons.

The Canal soldiers on….. through the Cold War



- **The American Iowa Class battleship New Jersey transiting the Canal in 1983. Note flanking PBRs, drag tug, and snug starboard clearance.**

Physical constraints on capital ship design

Nice comparison between an Iowa Class battleship from the early 1940s and a Panamax bulk hauler, constructed in the 1980s. They are transiting the canal in one-way traffic, westbound, through the Pedro Miguel Locks.

Both are deep draft vessels with beams slightly over 108 feet, allowing less than 12 inches clearance on either side.

- On October 13,1986 the eastern side of the Cucaracha Slide reactivated, spilling 526,000 yds^3 of debris into the canal, narrowing the opening to just 115 ft! The slope had crept 13 ft towards the canal during the previous four years, before rupturing.
- The Canal's experienced pilots were able to keep ships moving at a reduced speed and the debris was removed using dredges. This triggered the establishment of an advisory panel that began examining slope movements throughout the canal, associated with aging.

Container Ships – an American Innovation

Steel containers were first used by the Pennsylvania Railroad in 1934 to curb stevedore pilferage!

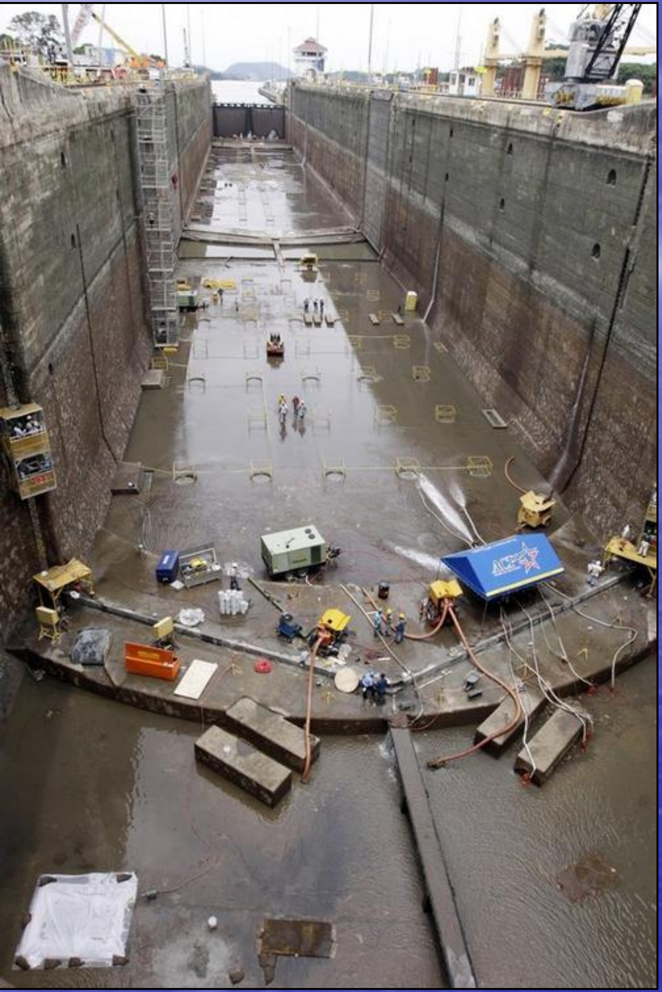
	Length	Draft	TEU
First Generation (1956-1970)			
Converted Cargo Vessel	135 m	< 9 m	500
Converted Tanker	200 m		800
Second Generation (1970-1980)			
Cellular Containership	215 m	10 m	1,000 – 2,500
Third Generation (1980-1988)			
Panamax Class	250 m	11-12 m	3,000
	290 m		4,000
Fourth Generation (1988-2000)			
Post Panamax	275 – 305 m	11-13 m	4,000 – 5,000
Fifth Generation (2000-?)			
Post Panamax Plus	335 m	13-14 m	5,000 – 8,000

Container ships have continued evolving into larger and larger vessels

Aerial View of the Construction Sites of the New Locks

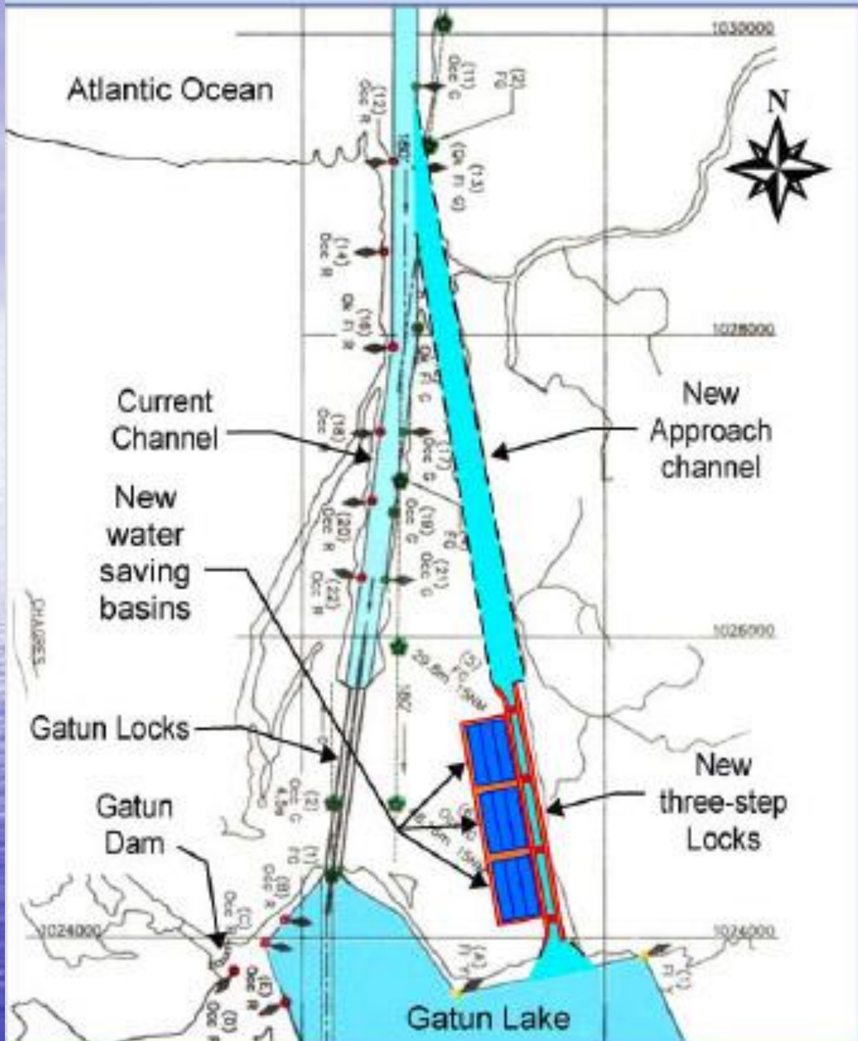
The Expansion of the Panama Canal (Third Set of Locks Project) 2007-14

The new canal is presently under construction



- The new Expansion of the Panama Canal (Third Set of Locks Project) was proposed by the Panama Canal Authority (ACP) in 2005, approved by 77% of Panamanian voters in 2006, and funded by the National Assembly in July 2007. It will double the capacity of the Panama Canal by 2014 by allowing more and larger ships to transit the Canal. The canal generates about half of Panama's revenue.

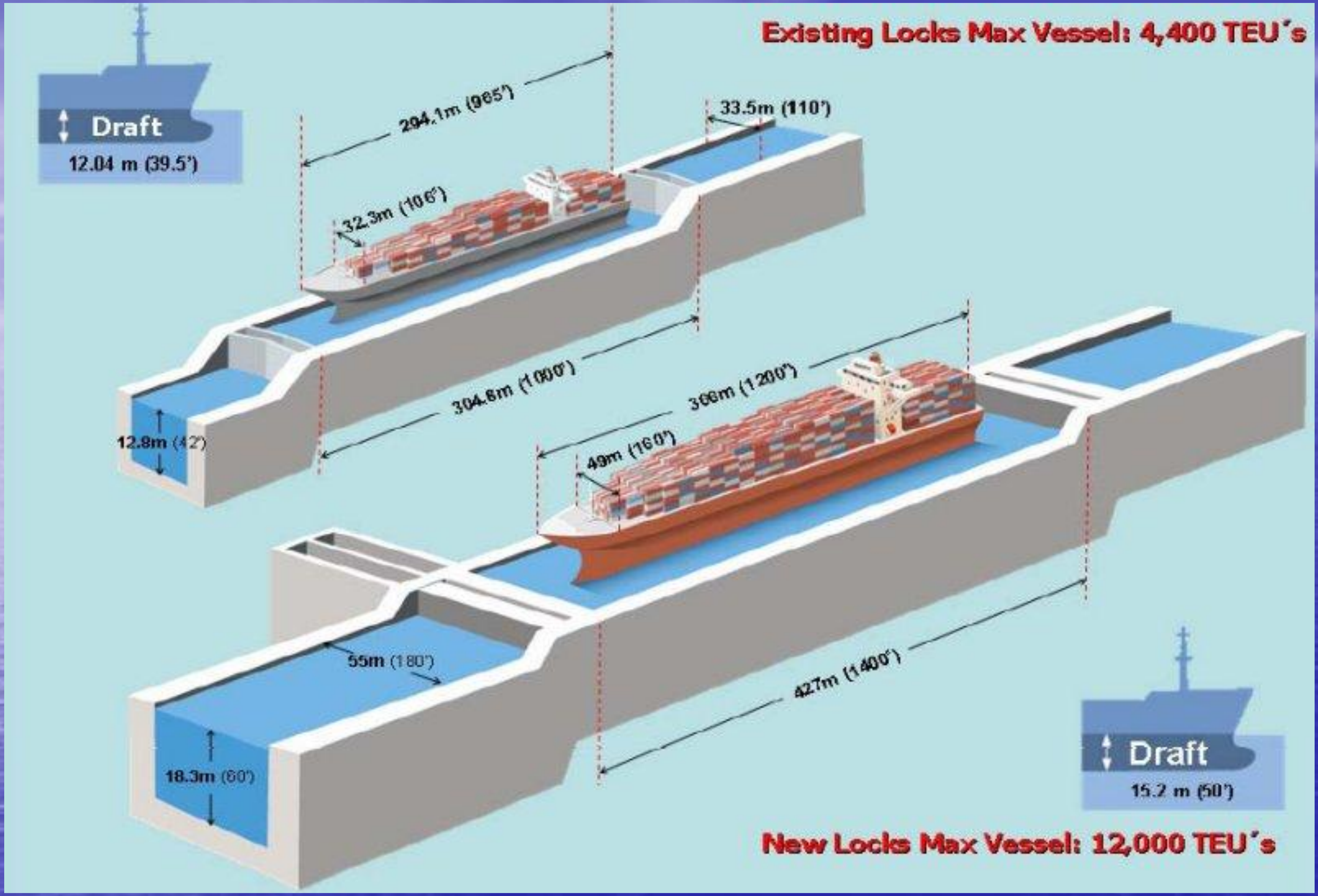
Conceptual Location of the New Atlantic Locks



Conceptual Location of the New Pacific Locks

- **The existing locks will be augmented by larger locks with water-saving basins, capable of transiting much enlarged container ships. Total cost about $5.2 billion, requiring seven years to complete.**

- **The new "bypass" locks will be about 300% larger than those constructed 100 years ago; from 1050 to 1400 ft long; from 110 to 180 ft wide, and from 42 to 60 ft deep. The larger locks will also employ water saving basins.**



- **The new Panamax vessels will be about 160 ft wide with a fully loaded draft of 50 ft, requiring navigation channels to be deepened to at least -55 ft.**

The future is now

- The next generation of Panamax vessels will carry ***240% greater payloads*** than the existing Panamax ships.