

The
Maintenance and Operation
OF
The Panama Canal

BY

JAY J. MORROW

(Colonel, United States Army, Retired)

GOVERNOR, THE PANAMA CANAL

A lecture delivered before the New York Section, American Society of Civil Engineers, in New York City, January 10, 1923; and repeated before the Society of Civil Engineers of Washington, D. C., January 17, 1923.



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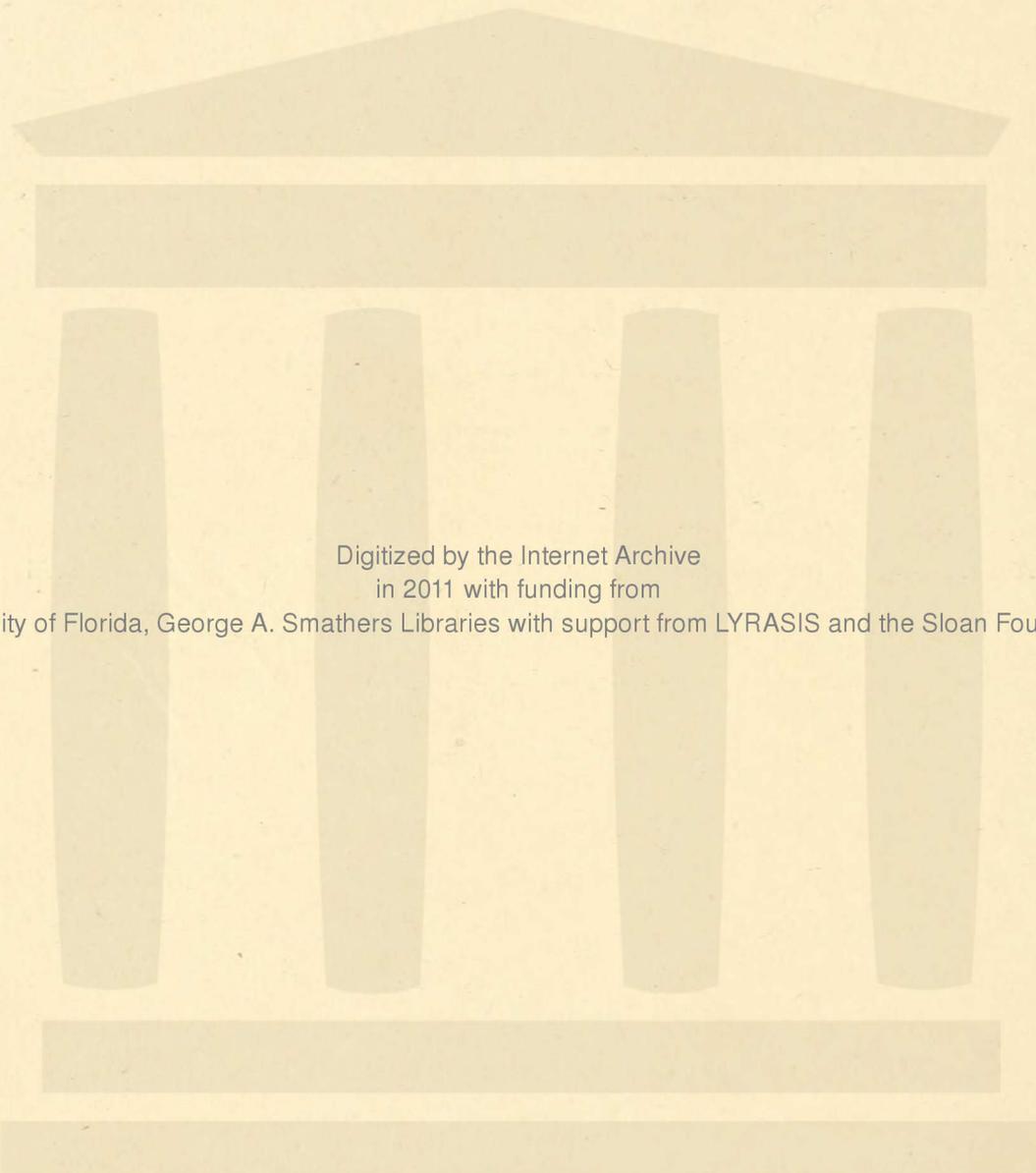
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THE MAINTENANCE AND OPERATION OF THE PANAMA CANAL

They that go down to the sea in ships, that do business in great waters;
These see the works of the Lord, and His wonders in the deep.—*Psalms*,
107; 23, 24.

The Panama Canal is the realization of one of the great dreams of the centuries. Into its building were woven the enthusiasm, the constructive and creative genius, and the patriotism of our highest type of men. From Roosevelt down to the adventurous roughnecks who actually made the mud fly, this spirit was everyday manifest and still lives after the great task is done. This article, which I have the honor to present, is largely a collection of facts—but an epic of cold and prosaic facts concerning a dream that has come true may have a beauty of romance surpassing those dreams of the imagination that never can become realized achievements.

In this presentation I have, so far as possible, limited myself to operation of the Canal since the close of the construction period. This, for the reason that most of you are more or less familiar with the construction problems and the achievements in their solution. However, in presenting the photographs it has appeared advisable occasionally to hark back to a construction view to call attention mainly to the unsatisfactory presentation of big construction which a completed Canal presents to the visitor.

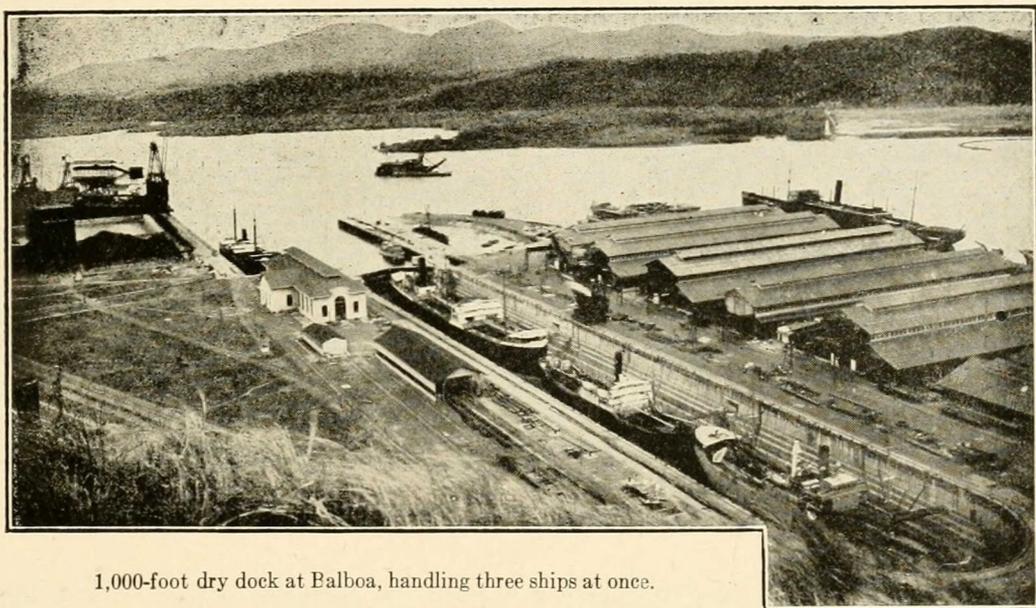
An intelligent view of the problems involved in the successful administration of The Panama Canal requires an understanding of the fact that we have at

Panama more than the artificial waterway for the passage of ships from ocean to ocean; in fact, there are three distinct factors in Canal administration: First, the operation and maintenance of the Canal; second, the administration of civil government for a community that includes 6,000 American civilians, 10,000 American soldiers and sailors, and 16,000 natives or West Indians, of whom 14,000 are employed by the Canal or dependent on employees, and the remainder farmers cultivating small patches in the jungle; and third, the operation of all kinds of auxiliary business enterprises attending the successful handling of the first two factors. I will first briefly outline these auxiliary business enterprises.

Our auxiliary enterprises include, among others, a railroad across the Isthmus and a steamship line between New York and Cristobal. The Panama Railroad antedates the Canal by half a century. Constructed originally, between 1850 and 1855, by American engineers and with American capital, it was subsequently acquired by the French Canal Company, and came into possession of the United States, together with the other French property on the Isthmus in 1904. The Panama Railroad still operates as a corporation; but all of the stock is government owned; the Secretary of War appoints the board of directors, and the Governor of The Panama Canal is President of the Company. The control of the railroad and steamship line was an important factor in the successful construction of the Canal, and is still essential to its economical and efficient operation. As common carriers they have earned more than \$20,000,000 profits in less than 20 years, which might have been much larger but for the policy of maintaining charges at a reasonable level. As a government-owned line we could not profiteer, or at any rate we did not. This can not be challenged

as successful operation by a quasi-governmental agency, especially when it is remembered that during this entire period all governmental freight and passengers were carried at very substantial reductions from commercial rates.

We have an office in Washington which handles our State's work, such as purchases and inspection of supplies and employment of skilled labor, as well as forming an admirable center for communication with all governmental bureaus, and particularly with the Secretary of War and with marine and other business interests.



1,000-foot dry dock at Balboa, handling three ships at once.

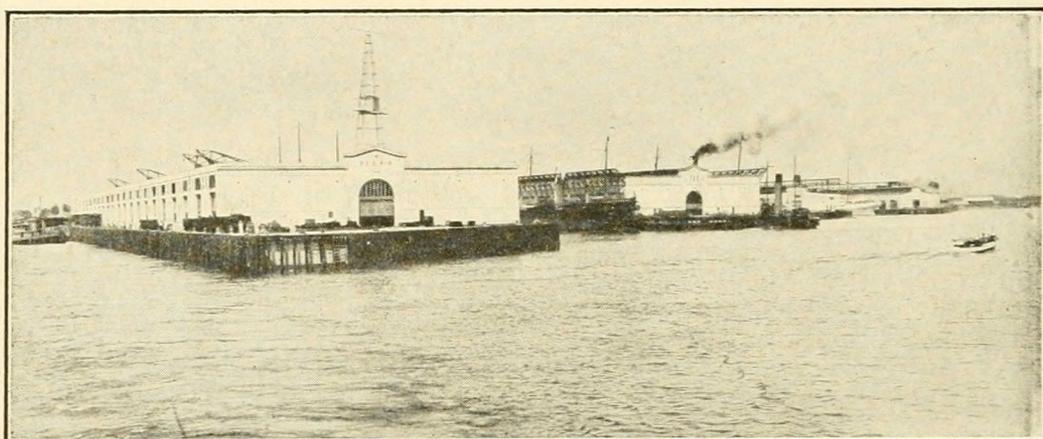
We operate two dry docks, one at Balboa, with the same dimensions as the Canal locks, 1,000 feet long and 110 feet wide, capable of handling any ship afloat, and a smaller dock at Cristobal, 300 feet long and 50 feet wide.

Adjacent to the Balboa dry dock there are modern shops equipped to handle marine repair work of any character or any extent, as well as car and locomotive repairs for the Panama Railroad and such maintenance jobs as the Canal and its equipment may require. Repair wharves, 3,500 feet long, adjoin the shops on the side opposite the dry dock.

At Cristobal there are shops on a smaller scale, capable of handling ordinary voyage repairs. A ship at Cristobal requiring repairs for which the facilities there are inadequate passes through the Canal free of tolls for repair at Balboa.

For vessels calling at Cristobal or Balboa to discharge or load cargo or for the convenience of passengers, complete modern terminal facilities have been provided.

At Cristobal there are three piers, each about 1,300 by 200 feet, with enclosed sheds 945 by 165 feet. There are also two wharves joining at an angle at Cristobal Point, with a total length of 1,500 feet and a width of



Piers at Cristobal, as seen on coming into port from the Atlantic.

about 100 feet, of which 80 feet is under shed. These terminals are of steel-and-concrete construction. The depth of water alongside is 41 feet at mean tide.

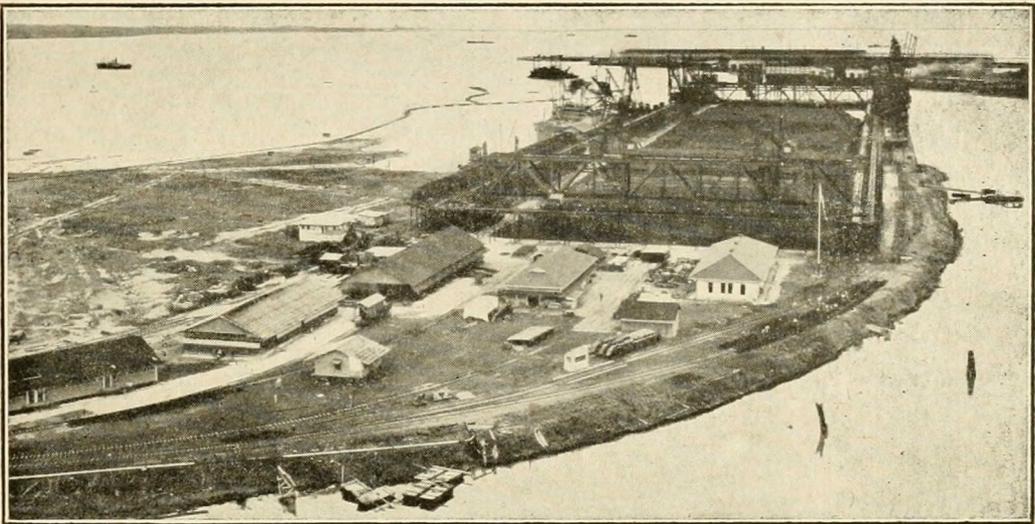
At Balboa there is one large pier 1,000 feet long and 201 feet wide, of the same construction as the Cristobal piers.

Including the wharves, the total area of docking at Cristobal is 855,000 square feet, and at Balboa 201,000 square feet, of which approximately 70 per cent is under roof.

A salvage steamer, fully equipped, is maintained ready at all times to proceed to the assistance of any

vessel in distress in the vicinity of the Canal, and sea-going tugs are available to pick up vessels that may require towing.

The coaling plants at Cristobal and Balboa have a combined storage capacity of 700,000 tons, and they are equipped with the most efficient handling machinery. Records have been made in the bunkering of ships which we believe have never been duplicated elsewhere—for instance, the following: The S. S. *Wiltshire* in November, 1920, took 1,102 tons in 1 hour and 25 minutes; the S. S. *Maimea* in May, 1921, took 656



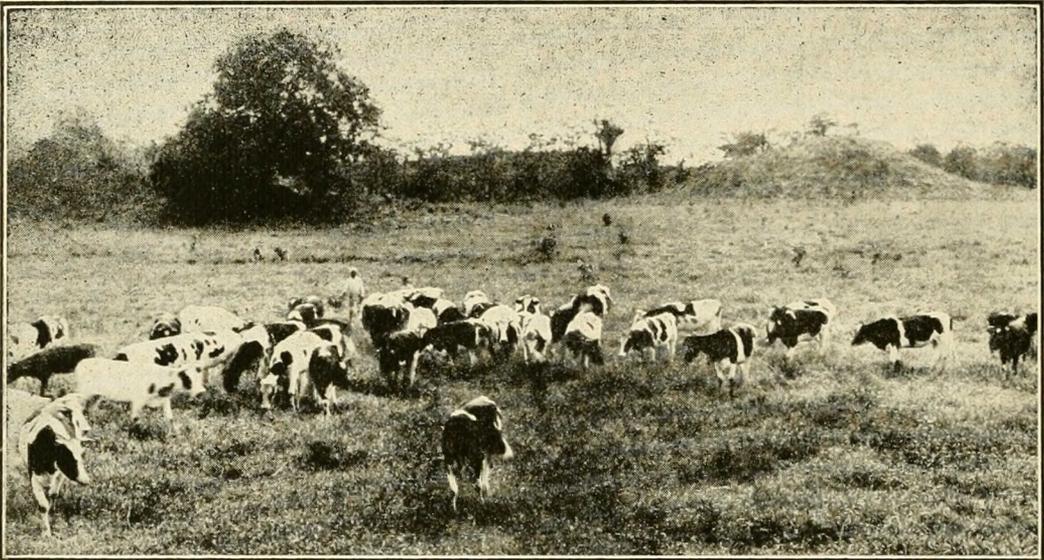
The 500,000-ton coaling plant at Cristobal.

tons in 45 minutes; the S. S. *Cape Henry* in May, 1922, took 285 tons in 20 minutes. These are bunkering figures and not cargo figures. The plant can give a collier a cargo of coal at 2,000 tons per hour. The coaling plants are supplied from Norfolk by our own colliers and barges, operated as part of the fleet of the Panama Railroad Steamship Line. There is no coal on the Isthmus except that handled by the Panama Railroad Company for The Panama Canal.

We have 10 fuel oil storage tanks, with an aggregate capacity of approximately 450,000 barrels. There are, in addition to these, 21 tanks, owned by 8 private

companies, with a total capacity of about 1,000,000 barrels, and new tanks are in process of erection. All oil is handled by central pumping plants at either terminal port, owned and operated by The Panama Canal.

From its storehouses the Canal is prepared to supply deck and engine room stores of every description, while the Commissary Department of the Panama Railroad Company can fill orders for provisions in any quantities, including fresh meats, dairy products, etc., in cold storage. The Commissary Department also operates a chain of small department stores from which our em-



Pasture land, with cattle.

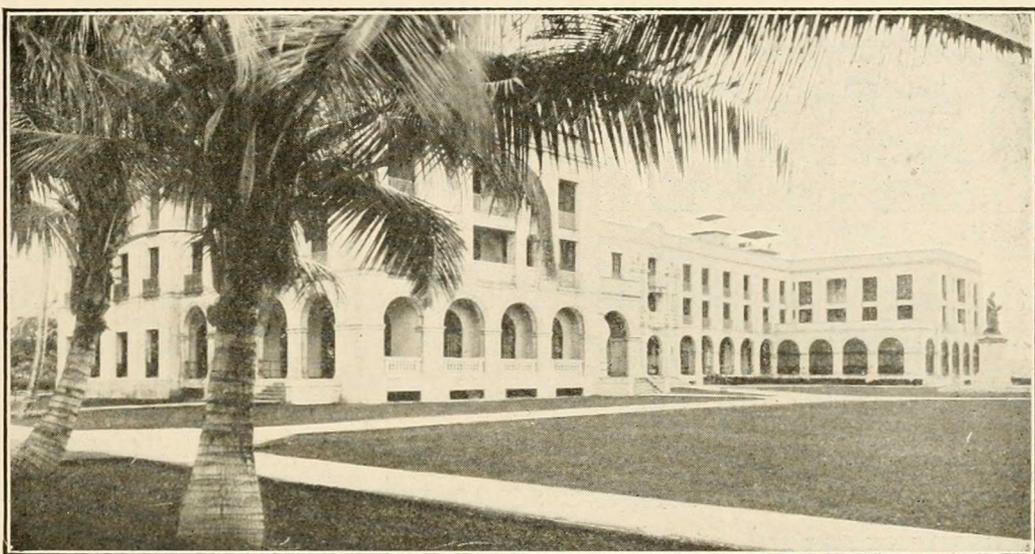
ployees and the personnel of the Army and Navy on the Isthmus can supply practically all of their wants.

In conjunction with our own abattoir and packing plant, we have approximately 50,000 acres of cleared cattle pastures, where we fatten stock imported from Colombia and other nearby countries.

Prior to May 1, 1922, the Canal operated a system of restaurants for its employees and for transients. These have now been leased. We still own and operate two first-class hotels, which we are also prepared to lease if we can get a satisfactory bid. We are inviting tenders for operating our beef, pork, and other wholesale businesses.

Some of these subsidiary business enterprises—for instance the coaling plants, packing plant, and commissaries—are operated by the Panama Railroad Company and with railroad funds, but except for purposes of accounting the distinction is unimportant. They are all integral parts of the Panama Canal organization.

To Americans unacquainted with the peculiar conditions on the Isthmus this intrusion of their Government into industries which are commonly conducted by private enterprise may cause surprise. No one can be more opposed that I am to ownership and operation



Hotel Washington, Atlantic side.

by the Government where individual or private control could possibly succeed. It is possible that with the development of trade at Panama there will come a day when the business is large enough to justify participation by one or more well-equipped companies, and when this time comes it will be found that the Government will gladly yield to private industry such parts of the work as can be effectively handled by ordinary business methods. Commerce requires and has a right to expect at the Canal certain conveniences, which the Government also requires, and it is my belief that under present conditions the Government can meet the demand

better than a private corporation could. The ships and operating force must have the service and until we can be assured that they will get it from others, the Government must furnish it.

An important part of our operations has to do with the housing of employees, caring for their health and furnishing wholesome amusements. Within the past year the housing, which had been at the cost of the Government up to January 1, 1922, has been placed on a basis where financially it maintains itself.

In the handling of its employees The Panama Canal is now practically on the same basis as the big industries in the tropics which are under private control, such as the United Fruit Company and other American corporations that are conducting operations at a great distance from the home base.

Under instructions issued by the Secretary of War, the subsidiary enterprises conducted by the Canal must pay their own way, or else we must show cause why they should be continued. In normal times this is not difficult, but during the past two years of deflation we have experienced the same troubles as other mercantile enterprises. For instance, we have had to take a loss on coal, cattle, and commissary stocks bought at the peak of the market, and the Panama Railroad Steamship Line has been affected by the slump in ocean freight rates and has lost money.

We are under one serious handicap in that our plant was designed to meet the possible military and naval requirements of the United States, and not merely for commercial operation. Our abattoir and packing house, for example, were constructed during the war when we had contracts for supplying beef to the Army. These contracts were subsequently canceled, and we were left with a plant on our hands that is too large for economical operation on the present reduced scale. The marine

repair shops, coaling plants, and fuel oil handling plants were designed to take care of the requirements of a fleet using the Canal as a base in time of war. At present we handle comparatively little coal or oil for the Navy, and get no important Naval repair work. This results in an excessive overhead on all of these plants except the fuel oil handling plant. The same comment applies to our hospitals, which are larger than normal use would warrant.

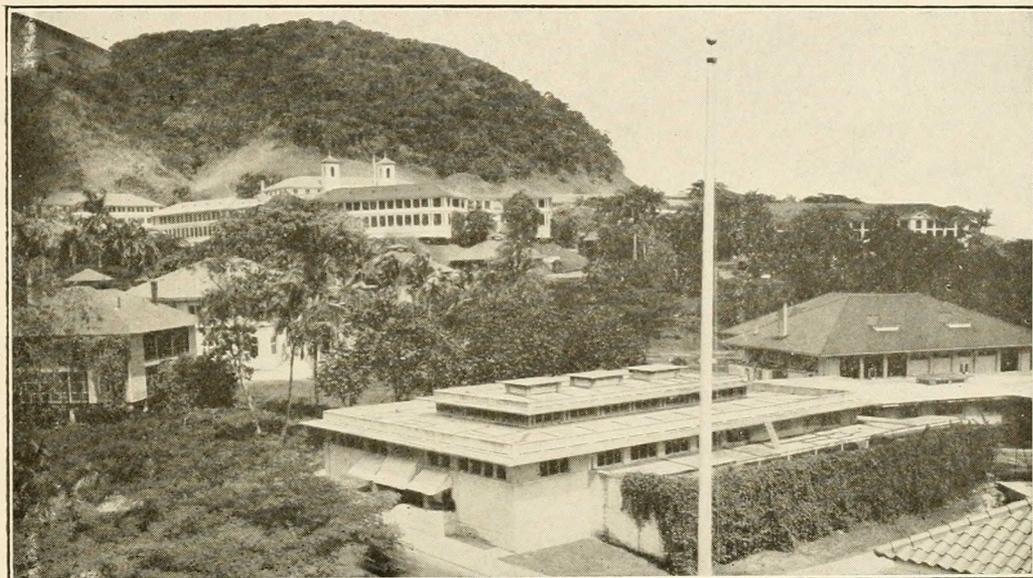
Our docks were intended for a transshipment business, which has not yet developed on the scale that was anticipated. The present tendency, in fact, is toward the development of through lines, with comparatively little transshipment at the Canal. A movement is underway at present, however, to extend the use of these wharf and storage facilities by a system of delivering cargo at Cristobal, there to await orders for transshipment elsewhere. A similar system is in use in various parts of the world. We are under obligations to the Republic of Panama not to shut her off from the benefits she naturally expects lying at a crossroads of the world's commerce, and our Government will meticulously observe this engagement. But under the treaty we have the right to ship goods through without duty restrictions. It is my belief that such a step would be of great convenience to commerce and of immediate benefit to the Republic of Panama, and therefore I venture to hope that at no distant date the Canal Zone will have only so much of the status of a "free port" as is covered by freedom to store goods in transit without customs restrictions or any expense except minor transportation charges and storage, enabling shippers by completion of bill of lading to obtain through rate. Under such conditions the system of wharves and piers which we have constructed at the Canal would not long be adequate.

The scale and capital cost of our various plants is justified on grounds of national defense, but they complicate the problem of economical administration in time of peace. It is only by careful management and close attention to detail that operating losses can be avoided. Nevertheless we do avoid them in the main, and over any considerable period of years our business operations will show a profit. With the gradual increase of commercial traffic, operating problems which are now difficult will find a natural and easy solution.

In addition to the operation of the Canal proper and its dependent business enterprises, our organization is charged with the government and sanitation of the Canal Zone. This includes public order and fire protection, the maintenance of streets, water supply and sewers, education, a postal service, quarantine, customs and immigration service, and services to American seamen.

When provision was made by Act of Congress for the operation of the Canal, authority and responsibility were concentrated in the President to be exercised by a Governor, reporting to the President, through the Secretary of War. The experience of the construction period had indicated very clearly that limited or divided authority on the Isthmus was inconsistent with efficient management. Nevertheless, proposals have been made from time to time and for various reasons which, if adopted, would have disrupted the present unity of control. For instance, it was recommended that the Division of Posts, the Customs Service, the Shipping Commissioners, and the Quarantine Service should be divorced from The Panama Canal organization and turned over to the various departments and bureaus which administer similar services in the United States. This would have resulted in vesting ultimate authority over these services in officials at Washington

with no knowledge of local conditions and to whom the Canal and its requirements would be of minor interest and importance. In the case of the quarantine officers, customs inspectors, and shipping commissioners, close cooperation with one another and with the port captains, pilots, and representatives of other Canal departments would be impossible, and the present efficiency of our service to shipping would be destroyed. There was nothing to recommend the scheme except that it would have reduced the apparent cost of operating



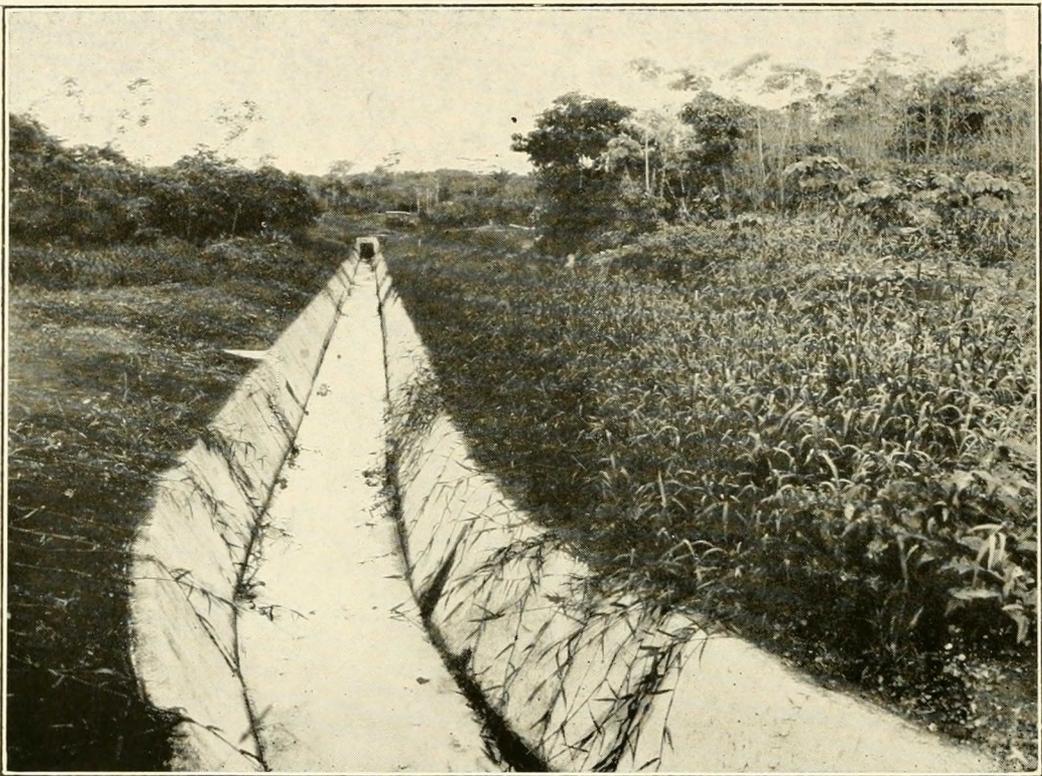
General view of Ancon Hospital; Commissary in foreground.

the Canal by transferring a part of the necessary force to other departments of the Government. The ultimate expense to the United States would undoubtedly have been greater than it is now. Fortunately, none of these recommendations have been approved.

It was also proposed, some months ago, to station a prohibition enforcement agent on the Isthmus who would report to the Director in Washington. There is no need for such an officer down there, as the Canal Zone police are quite capable of excluding liquor from the Zone, which is probably the driest territory under

the flag, and his appointment would have been inconsistent with the principle of concentrated authority and responsibility.

Sanitation has always been of supreme importance at Panama. When we went there, in 1904, yellow fever was endemic, there were frequent outbreaks of bubonic plague, cholera, and smallpox, and the entire population was debilitated by malaria. All of these diseases, except malaria, have been stamped out, and the

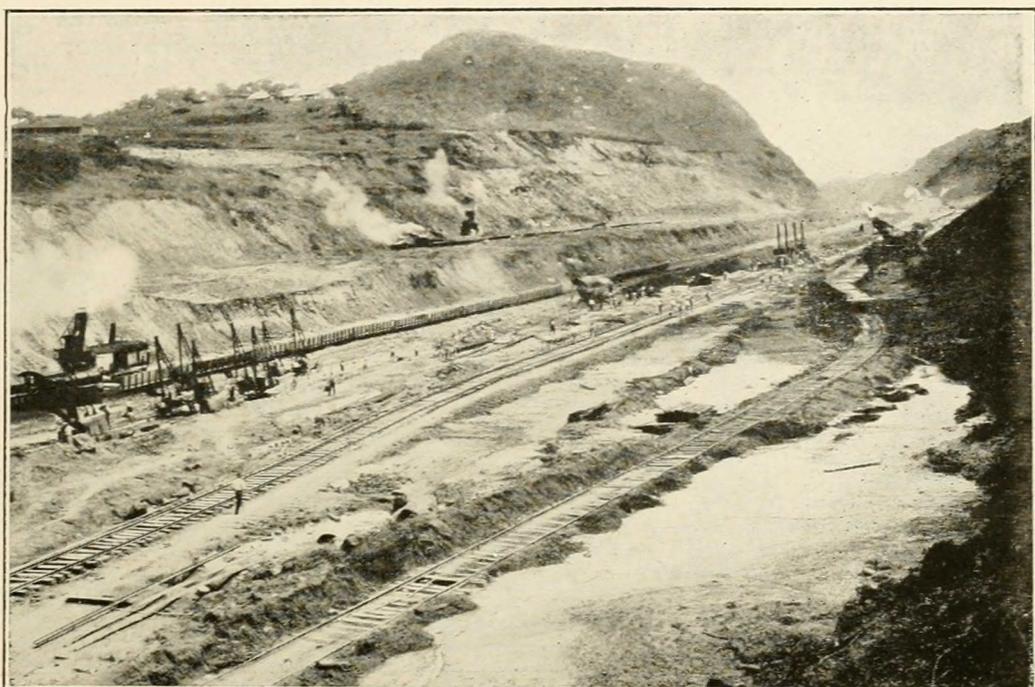


Permanent drainage ditch.

malarial rate has been reduced to an almost negligible figure. This has cost money, and the expenses of sanitation are still heavy, but since 1919 we have found it possible to reduce the force of sanitary inspectors and their gangs by nearly 50 per cent, without increasing the sick rate or lowering our standard of protection. We have simply profited by our own experiences, substituting economical methods for others that were wasteful without being more effective, and gradually increased the permanent ditch work.

What I have said will indicate in a general way the variety and complexity of the administrative problems involved in the operation of The Panama Canal. Most of the major engineering problems were solved during the construction period, but I will now turn to certain features in the working of the Canal proper which may be of more immediate interest to engineers.

No problem encountered in the construction and operation of the Panama Canal has given rise to so

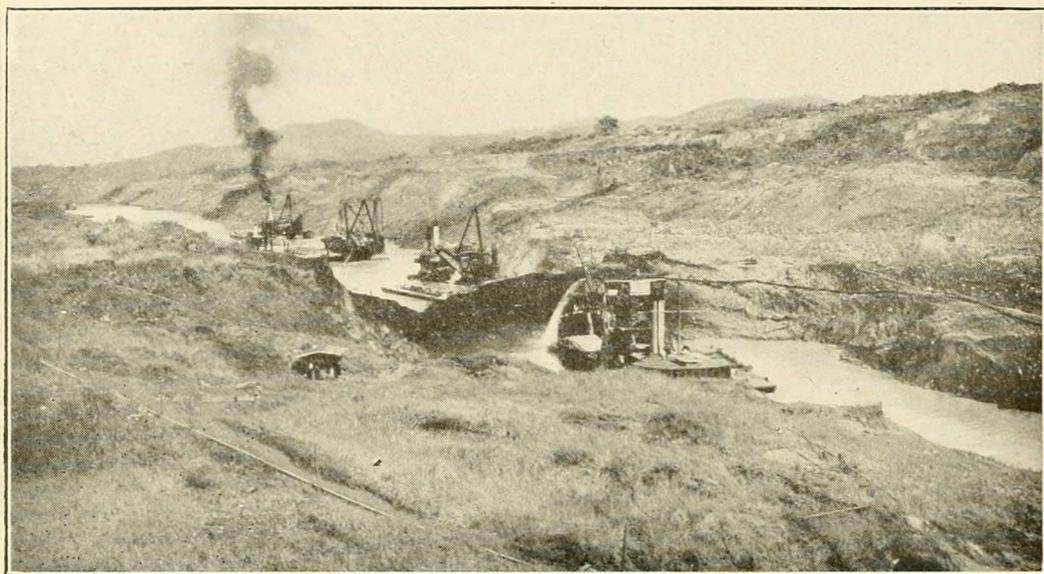


Section of Gaillard Cut near Culebra in 1909—4 years before final grade was reached.

much discussion as the slides in Gaillard Cut. They are confined to an area extending less than 1 mile on either side of Gold Hill, where the excavation was deepest, but they seriously interfered with construction work, and blocked the Canal once for 6 months after it was opened to navigation.

The most serious of the slides, the only one in fact that has been really disastrous, involved a simultaneous movement of both banks at East and West Culebra, north of Gold Hill, which, in September, 1915, completely blocked the channel with a ridge of earth and

rock 250 feet wide and rising 65 feet above the water level. From September, 1915, to April, 1916, the Canal was closed to navigation. During that period the dredges worked 24 hours a day, Sundays and holidays included, until the channel was restored. During the fiscal year 1916, which included the period of this slide, more than 12,000,000 cubic yards of material were removed from Gaillard Cut. It is of interest to record here that in one day of 24 hours, working three shifts, the dredge *Cascadas* removed 23,305 cubic yards of rock from Culebra slides, about 35,000 tons. This

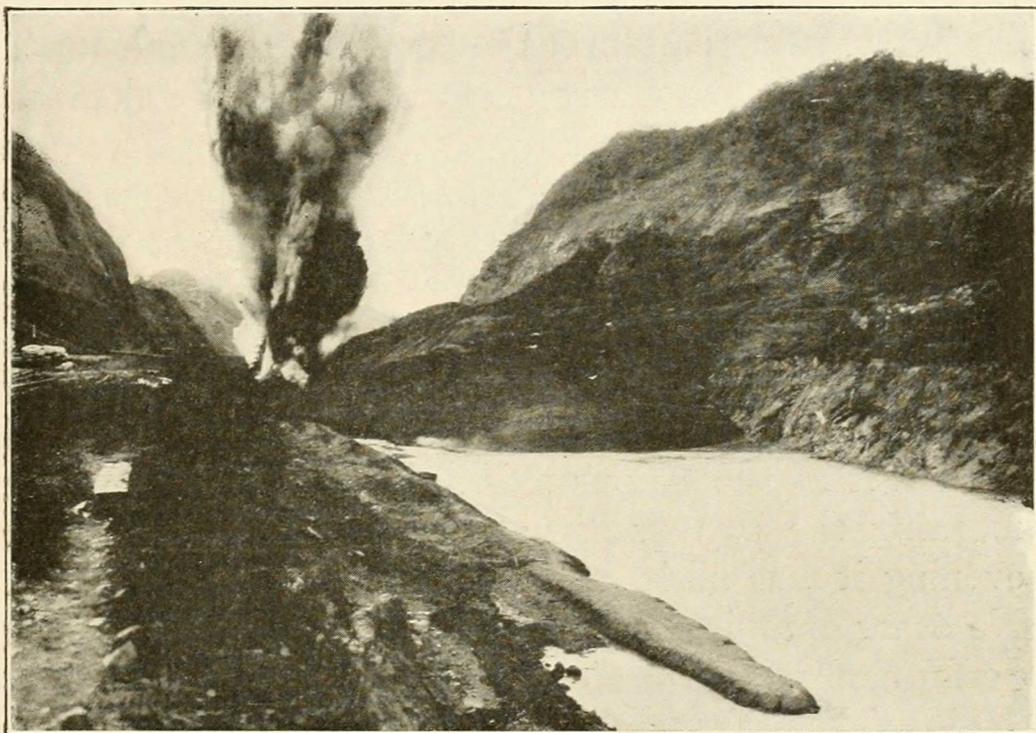


Cut looking north from west bank, showing complete blocking of Canal channel by slides from east and west banks, November 18, 1915.

means averaging a 15-yard dipper load every 55 seconds. Shifting of scows consumed some time. The dredge actually worked at the rate of 40 seconds to the 15-yard bite. That rock was being moved at about the rate of $\frac{1}{2}$ -ton per second. The record of a sister dredge, the *Paraiso*, 17,000 yards, comes next to this, and it is believed that even this figure tops any dipper dredge 24-hour record in 45-foot depths.

The Cucaracha slide, on the south side of Gold Hill, is the oldest of the slides and was the most persistently troublesome in the construction period. It is said to

have begun to move when the French were working there, in the early 80's, and several times during the dry excavation by the Americans it pushed across the Cut, overturning trains and tracks, and banked up against the opposite side. When water was admitted to the Cut from Gatun Lake, in October, 1913, Cucaracha slide blocked its passage to the south end of the Cut. A sluiceway was dug and blasted through the base of the slide, to allow the water to fill the south end of the



Cucaracha Slide extending into Cut—October, 1913.

Cut, after which dredges attacked it from both sides. The channel was cleared to full width and depth by the time the Canal was opened to commerce, on August 15, 1914.

In August, 1916, a movement of the Cucaracha slide, south of Gold Hill, caused a suspension of traffic for 8 days, and a movement of the East Culebra slide in January, 1917, caused another suspension for 2 days.

There was no further trouble of serious importance until February 21, 1920, when a general movement occurred in the Cucaracha slide, carrying huge masses

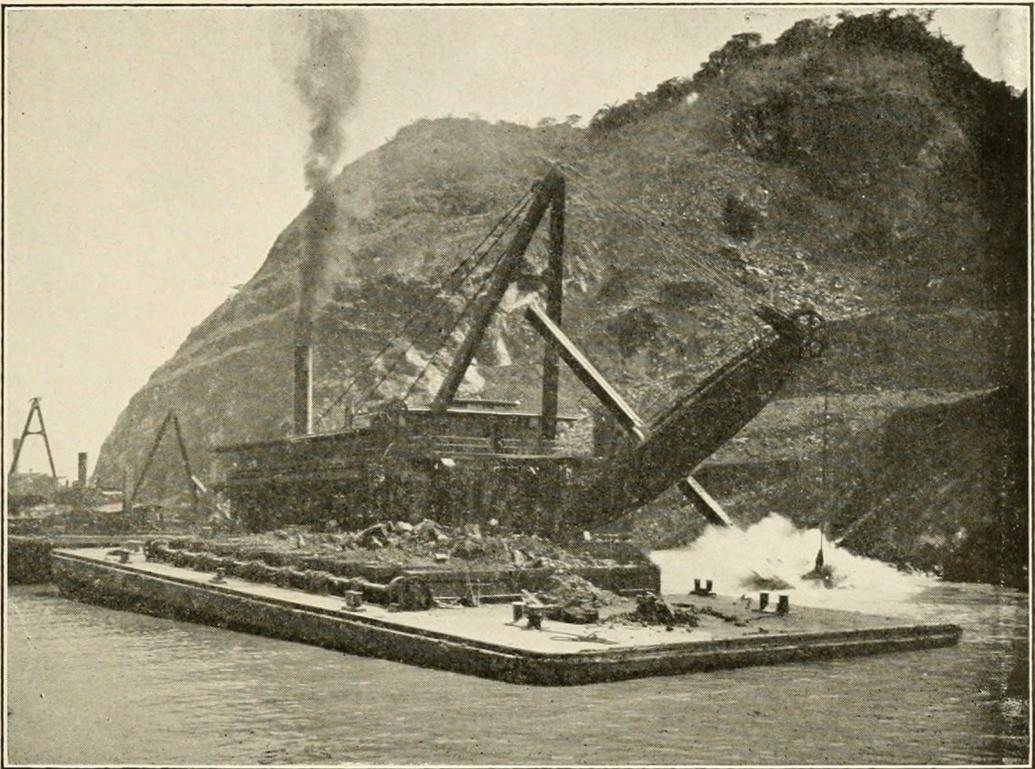
of earth and rock into the Canal prism, and for 3 months giving intermittent obstruction to traffic. The operation of the large dipper dredges accomplished the removal of the obstruction at a sufficient rate to keep the Canal open to all traffic, with exception of occasional delays in February, March, April, and May, 1920, 27 ships being delayed for 54 ship days, with a maximum delay to any one ship of 4 days.

During this movement of 1920 some of the hard rock that had sheared off the south face of Gold Hill years earlier, when the softer rock under its mushroom-shaped top had given away, was pushed out into the channel. The dredges could not move a mass of large pieces or a single piece which lay close to mid-channel and measured 60 feet in length, 30 feet in breadth, and 20 feet in depth, with 25 feet of water over it. This was the size of a large 2-story house, and under 25 feet of water. The drill barge *Teredo* was placed over this rock at 7 o'clock one evening. She drilled it, charged it, and blasted it in one 8-hour shift. At 7 o'clock the next morning the two dredges tackled it and by 5 that evening it was all in barges on its way to the dump. No other organization in the world can duplicate that performance.

Since then, though there have been slides of minor importance, traffic has not been suspended or delayed.

A slide movement occurred on the afternoon of July 14, 1921, on the east side of the Cut, one-half mile north of the Culebra slides, which carried 185,000 cubic yards of material into the prism, and left the Canal only 150 feet wide along the west bank, with a channel of but 100 feet width and 20 feet depth. We were lucky in that that day's traffic had passed; the slide occurred about 3 p. m. For the next day's traffic we had a channel of 150 feet width and 30 feet depth, and that day's traffic went through, and on the second day three of

our largest dreadnaughts, carrying our diplomatic mission to the Peruvian Centennial, passed through, all on their schedule time. No ship was delayed. This operation gives a fair idea of the dependability of our Dredging Division. When the slide moved, one dredge was operating in the Cut a mile-and-a-half distant. She took out her first dipper load in 50 minutes. The other was working in Balboa Harbor, and had to be



Fifteen-yard dipper dredge at Cucaracha Slide—June, 1914.

towed up through 3 locks and 9 miles of Canal. She was at work in 7 hours.

We had another movement on December 21, 1922, at the north end of East Culebra, which put 150,000 yards into the prism and about 450,000 yards additional into the dredged basin. Two dredges jumped right on it and for next day's traffic had 35 feet by 150 feet width through the bar. The force worked through Sunday and Christmas day, and the channel was almost cleared before New Year's. One hundred and twenty-

seven thousand yards were moved in 10 days with two dredges, each working 16 hours.

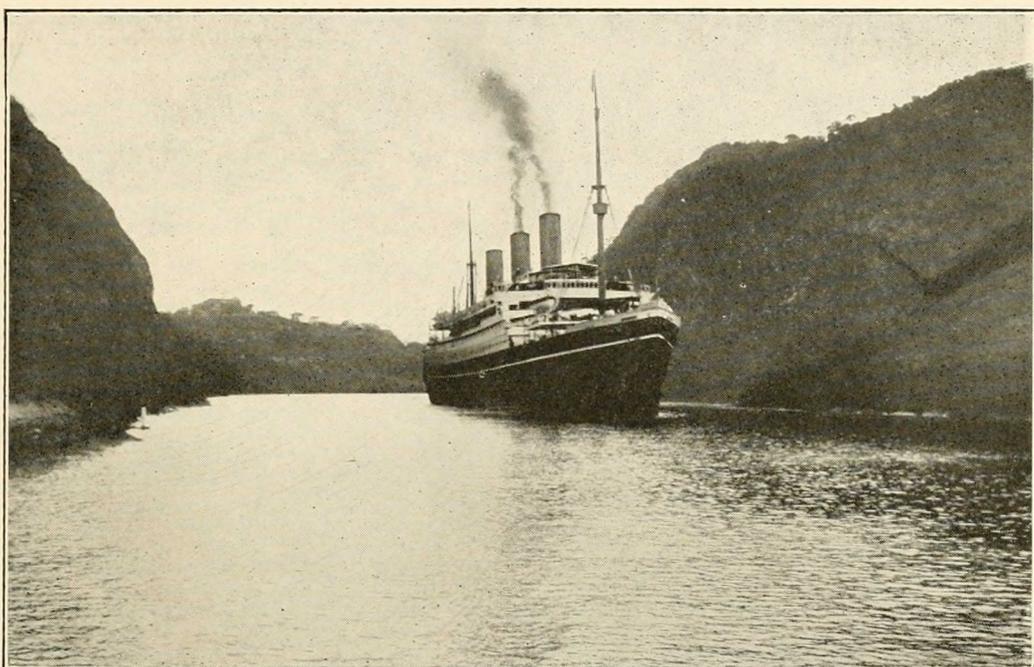
Since the opening of the Canal the dredges have removed from the Gaillard Cut more than 37,000,000 cubic yards of material, the greater part of it chargeable to slides. The excavation in the Cut last year totaled slightly less than $1\frac{1}{2}$ million cubic yards.

We believe we no longer have a serious slide problem. The three great slides, at East and West Culebra and Cucaracha, the sources of all uneasiness and controversy, and the only ones that have caused appreciable trouble, have already been controlled and are almost dead. There is of course a possibility that these areas may be extended somewhat in the future, and other smaller slides may occur, but serious difficulty is not apprehended.

In dealing with the slides, of all the theories that were tried which were at all applicable to a work of this magnitude—and they were many—none has been found to be practical but that which was developed under General Goethals in the construction days. This consists of the removal of material at the base of the slide by the dredges until an angle of repose has been obtained, assisted by a system of surface drainage and closing of peripheral cracks by hydraulic grading. These methods have been based on first-hand knowledge of perhaps the most diversified geological formation ever encountered in excavation and experience with the deepest open cuts ever made. Even with the aid of the best geologic knowledge obtainable, experience was found to be the best guide.

The slides are now important, mainly because they slightly increase the cost of operation by compelling us to hold in reserve dredging equipment in excess of what would be required for the ordinary maintenance of the channel; an emergency may arise at any time, and we must be prepared to meet it instantly.

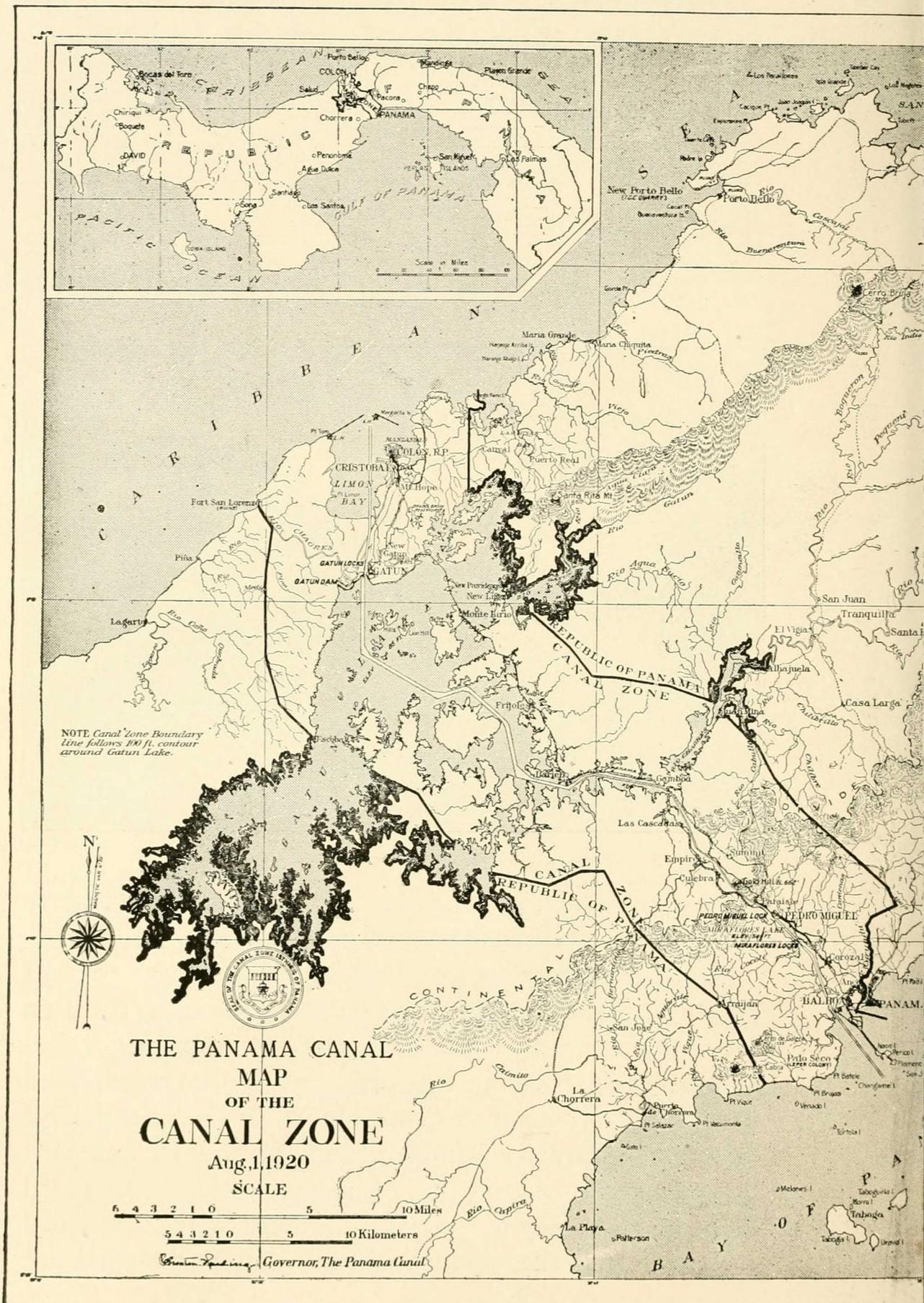
Some of our excess dredging equipment can be used to advantage, while it is not otherwise employed, in giving additional width to the channel at bends where navigation is difficult. It is now being used to cut off the so-called La Pita Point. This work is not now essential, but it makes for easier navigation, and will be essential when traffic has increased to the point which will force night navigation through the Cut. During its completion it serves to keep busy for 3 or 4 years

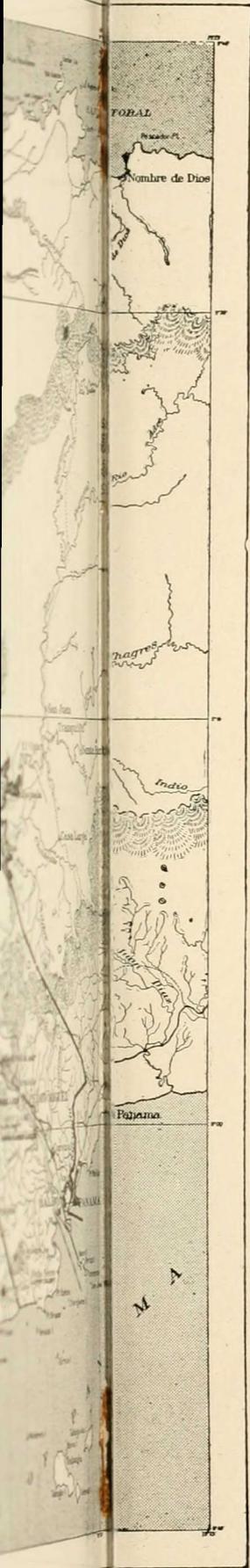


Gaillard Cut as it appears today—the *Empress of Australia*.

equipment which we are obliged to maintain as insurance against such slides as the one of July, 1921.

While the slides are no longer a menace under present conditions, they would prove a most serious factor if an attempt were ever made to convert the lock canal into a sea-level canal, a project frequently resurrected under the alluring designation of "The Straits of Panama." Given unlimited time and money, it might be feasible to carry the excavation in the Gaillard Cut 85 feet deeper, but no engineer with first-hand information of the conditions would attempt to estimate

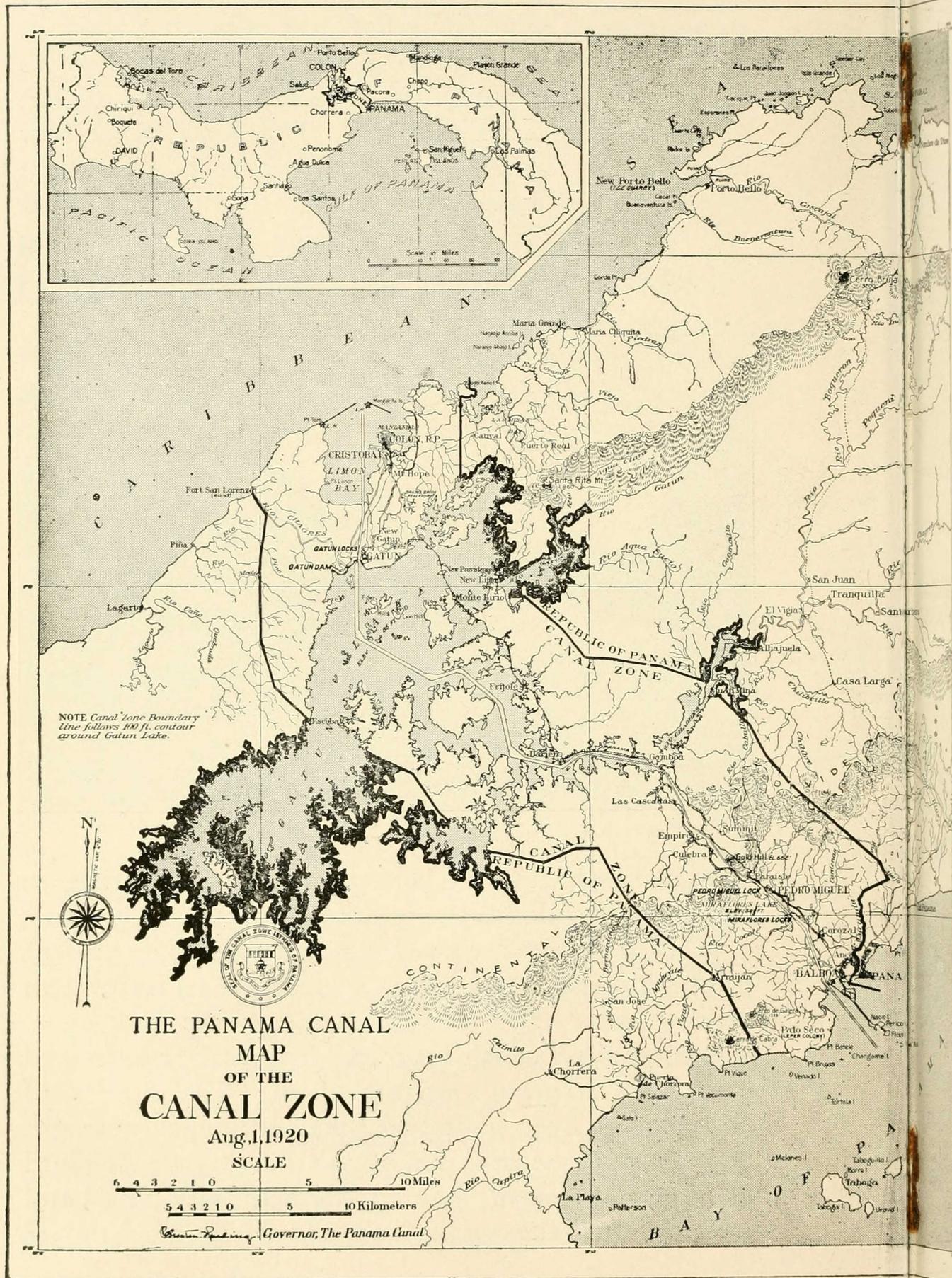




either the yardage or the cost. There are other objections to the sea-level project, notably the difficulty of controlling the Chagres River and the other large streams which now discharge into Gatun Lake; and it may be doubted whether any sea-level canal of feasible cross section would permit of a heavier traffic than the present lock canal. The sea-level canal has little to recommend it, since all arguments based on the element of safety are nullified by an experience which extends now over a period of 8 years, and proves conclusively that the passage of a vessel through the present Canal is attended by no risk that is not inseparable from the handling of ships in narrow waters. From the sea to the locks our present channel is 500 feet wide, through the Gatun Lake from 500 feet to 1,000 feet, and through the Gaillard Cut, which is less than 9 miles long, 300 feet. There is no part of the Canal in which two ships can not pass with safety, and, except at rare intervals when the slides were acute, it has never been necessary to tie up a ship in the Canal. For that emergency, mooring stations have been provided on either side of the slide area. The speed permitted ships in transit varies from 6 to 15 knots, according to the width of the channel, and the passage from ocean to ocean requires but from 6 to 7 hours. No practicable sea-level canal could provide channels of this width or permit of so rapid a transit.

A feature of lock operations at the Panama Canal which is novel, is the use of electric locomotives to tow vessels through the locks. These locomotives operate on tracks laid upon the lock walls parallel to the chambers. For a small vessel 4 are used, 2 ahead, on either bow, towing, and 2 astern, holding back. For larger vessels 6 and 8 locomotives are used, in which case 1 or 2 pair travel amidship.

This system was designed primarily for safety, as it insures absolute control of a vessel while it is in the

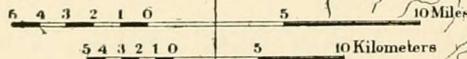


NOTE Canal Zone Boundary line follows 100 ft. contour around Gatun Lake.

THE PANAMA CANAL
MAP
OF THE
CANAL ZONE

Aug. 1, 1920

SCALE



Walter H. Anderson, Governor, The Panama Canal

either the yardage or the cost. There are other objections to the sea-level project, notably the difficulty of controlling the Chagres River and the other large streams which now discharge into Gatun Lake; and it may be doubted whether any sea-level canal of feasible cross section would permit of a heavier traffic than the present lock canal. The sea-level canal has little to recommend it, since all arguments based on the element of safety are nullified by an experience which extends now over a period of 8 years, and proves conclusively that the passage of a vessel through the present Canal is attended by no risk that is not inseparable from the handling of ships in narrow waters. From the sea to the locks our present channel is 500 feet wide, through the Gatun Lake from 500 feet to 1,000 feet, and through the Gaillard Cut, which is less than 9 miles long, 300 feet. There is no part of the Canal in which two ships can not pass with safety, and, except at rare intervals when the slides were acute, it has never been necessary to tie up a ship in the Canal. For that emergency, mooring stations have been provided on either side of the slide area. The speed permitted ships in transit varies from 6 to 15 knots, according to the width of the channel, and the passage from ocean to ocean requires but from 6 to 7 hours. No practicable sea-level canal could provide channels of this width or permit of so rapid a transit.

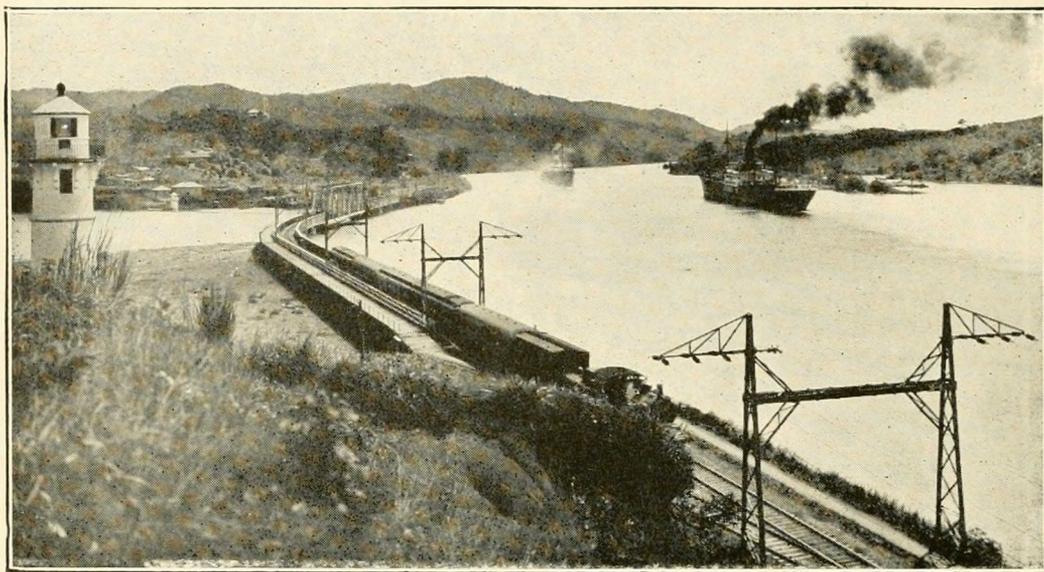
A feature of lock operations at the Panama Canal which is novel, is the use of electric locomotives to tow vessels through the locks. These locomotives operate on tracks laid upon the lock walls parallel to the chambers. For a small vessel 4 are used, 2 ahead, on either bow, towing, and 2 astern, holding back. For larger vessels 6 and 8 locomotives are used, in which case 1 or 2 pair travel amidship.

This system was designed primarily for safety, as it insures absolute control of a vessel while it is in the



locks, and prevents contact with the lock walls or gates, which could not easily be prevented if vessels proceeded under their own power or were warped in with capstans or winches. It has the further important advantage of greater speed than would be possible under any other system of maneuvering vessels through the locks with the precautions which that operation requires.

The necessity for these towing locomotives has occasionally been questioned, and we have been asked why we can not employ the methods of the Sault Ste.



Ships about to pass at Gatun Lake end of Gaillard Cut.

Marie Canal, where thousands of vessels annually pass through the locks under their own power. The conditions are in reality entirely dissimilar. Ships on the Great Lakes are of specialized and uniform design, built with conditions at the Soo in mind, and equipped with mooring and towing machines, checking devices, and emergency signalling apparatus between the bridge and the engine room. They are of comparatively low draft and are handled much more easily than vessels of greater draft. Their crews speak English and have no difficulty in communicating with the lock operators, and since they pass the locks on an average once in

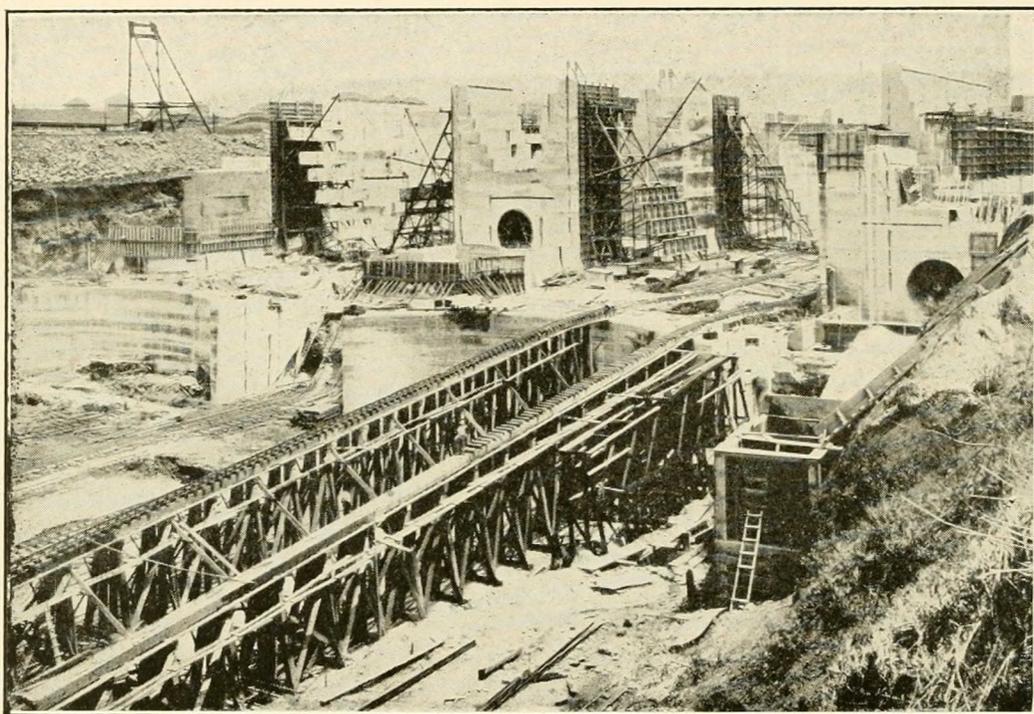
every 5 days during the season, they soon become trained in the required maneuvers. These radical differences render any conclusions drawn from practice at the Soo of little value on the Panama Canal.

At Panama no single feature has contributed more to the safe, orderly, and rapid transit of vessels through the locks than these towing locomotives. They can not be criticized except on the score of expense, and that is fully justified by the results obtained. The masters of ships using the Canal would probably be the most vigorous opponents to any change in the present system.

The gates, valves, fender chains, and all operating machinery installed at the locks, have all justified their design and proven to be exactly adapted to the purposes for which they were intended. This simple statement speaks volumes for the work done by Goethals, Hodges, Schildhauer, and Goldmark. Economy, as well as safety and efficiency, has been attained, the control boards having been so arranged that one operator can handle every movement required to put a vessel through a lock or an entire flight of locks. The operation of the locks, while it involves nothing more than a combination and adaptation of well-known devices, is, nevertheless, an impressive example of mechanical efficiency.

While the Canal is adequately lighted for navigation at night and it is entirely practicable to operate on the basis of a 24-hour day, ships are not now dispatched unless they can pass through the Gaillard Cut during the hours of daylight. There are two reasons for this restriction. The present volume of traffic, with an average of about 10 ships a day, does not justify the expense of continuous operation, and as long as dredging operations require two shifts it is desirable to keep the Cut clear at night for our own dredges, tugs, and scows engaged in maintenance work.

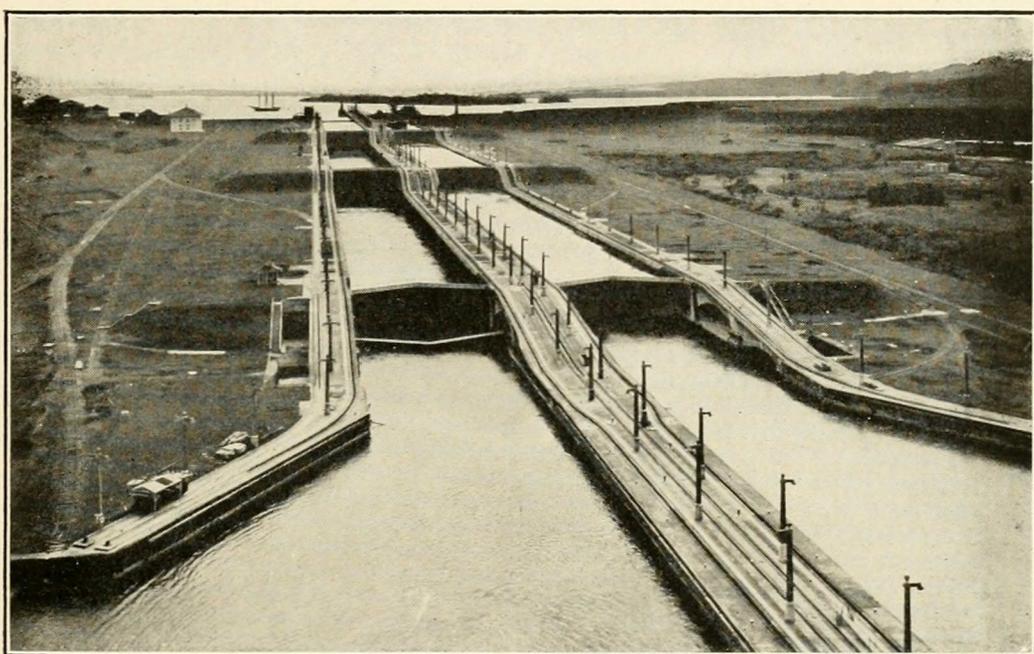
During the administration of my predecessor, Gen. Chester Harding, studies were begun to develop a method of dispatching ships which would permit us to reduce the lock-operating force without interfering with the rapid passing of vessels through the Canal. It had been the practice to dispatch vessels within the established time limits without any systematic effort to space them other than was necessary to avoid obvious congestion. This required a force at the locks which the study has proven could be reduced.



Gatun middle locks under construction—April, 1911.

The operators, in addition to the one man in the control tower, are engaged alternately on the towing locomotives and on maintenance work. When two or more vessels arrived at one time, as frequently happened, it was necessary to take men off maintenance work to man the additional locomotives that were required, and time was lost. We have three shifts of operators at each lock, and we proposed so to arrange the work that one shift or at most two, could normally take care of lockages, while the other was employed on maintenance work

without interruption. With this object in view, a system was worked out of dispatching ships on a fixed schedule, so that they would arrive at the locks at regular intervals and at predetermined hours, and this system was placed in operation in August, 1921. Steamship companies and American chambers of commerce on both coasts registered emphatic protest when the schedule was first introduced, under the misapprehension that adherence to the dispatching schedule would cause delays to shipping. These protests were



Gatun Locks.

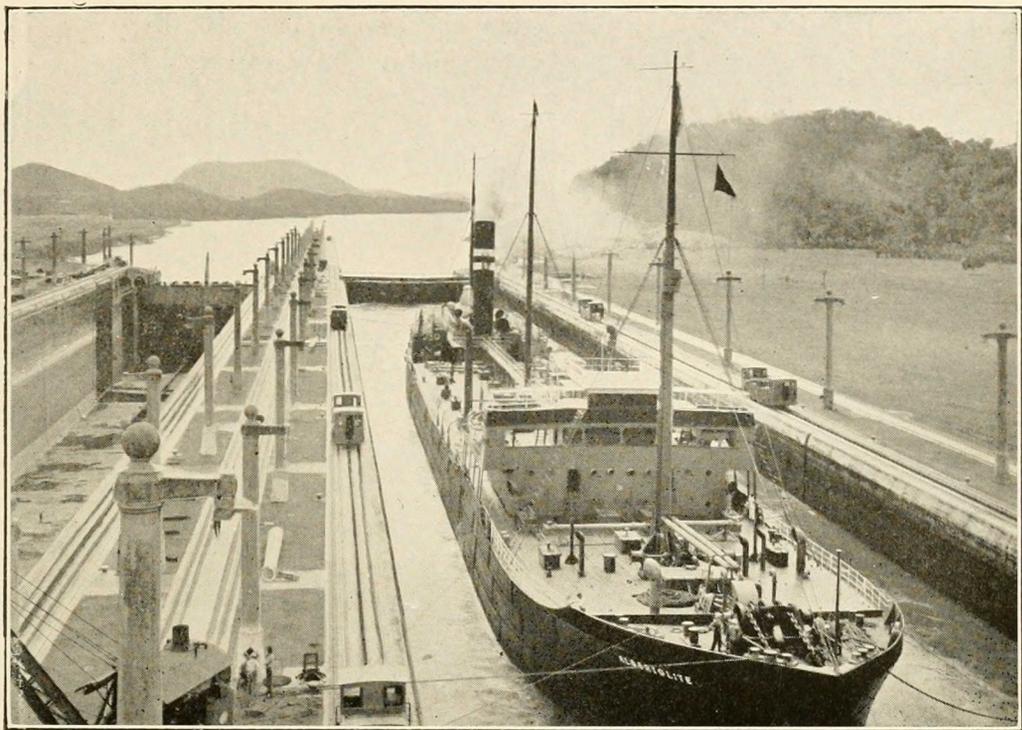
in some cases based on the erroneous belief that the Canal, to save a few dollars, was substituting a limited operating day for continuous operation. But the navigation of the Cut has always been restricted to the hours of daylight. When our forces and the masters of vessels became accustomed to the operation of the schedule it was found to work smoothly. The schedule itself has been modified and given greater elasticity as experience dictated. Besides permitting a more economical operation of the locks, it makes for safer navigation by insuring the arrival of vessels at the locks when

there are no adverse currents set up by lock operations. Vessels arriving at Cristobal inner harbor prior to 1.30 p. m. and at Balboa inner harbor prior to 1.45 p. m. are put through the Canal on the same day. When the southbound traffic is light, vessels are dispatched from Balboa provided they can arrive at the first lock prior to 3.30 p. m. These are substantially the same hours as under the old rules. A materially better service is impracticable while the navigation of the Gaillard Cut is restricted to the hours of daylight, and it will be some years before the volume of traffic will justify night operation.

It was found advisable at an early date in the operation of the Canal to detail special pilots to take vessels through the locks, rather than to leave the channel pilot in charge during the entire transit. This was to insure the closest possible coordination between the pilot on the bridge and the towing locomotive operators on the lock wall, who operate under the pilot's signals. This system is open to the objection that a pilot unacquainted with the steering qualities and other peculiarities of a ship is placed on board at a short distance from the approach wall and then takes charge of the difficult operation of entering the lock. For this reason, in the winter of 1921-1922, the lock pilots were taken off at Gatun for 6 months, and the channel pilots were allowed to take their vessels through these locks. As a result of this experiment we returned to the original lock-pilot system. There are two lock pilots assigned to each lock; they board approaching vessels at not less than 300 yards from the approach wall, and leave them after the towing locomotives cast off in the last chamber. Occasionally, when a lock pilot is not immediately available and a vessel might otherwise be delayed, the channel pilot will take her through the locks; and on days when the traffic is unusually heavy, lock pilots

are withdrawn from their usual duties to act as channel pilots. But the usual rule requires the special pilot at each lock.

In the Marine Division, The Panama Canal has built up an organization of unquestioned efficiency for handling vessels in transit and capable of meeting any demands which may be made upon it. This division has always been headed by a captain of our Navy. Its efficiency was tested in January, 1921, when the



Oil tanker in Miraflores Locks; tankers are an important feature of the traffic.

Atlantic Fleet passed through the Canal for maneuvers in the Pacific. In 2 days a total of 32 naval vessels, including battleships of great beam and draft, and 9 commercial vessels, made the complete transit from Atlantic to Pacific, and 2 commercial vessels from Pacific to Atlantic. This is the heaviest traffic that has yet been handled in the same length of time.* It did not approach the capacity of the Canal, but it

* These records made in January, 1921, have since been surpassed. The record number of transits for one day, 38, was made on February 15, 1923, when 14 commercial vessels, 5 battleships, 13 submarines, 3 minesweepers, 2 barges, and a naval auxiliary ship passed through the Canal.

On May 25, 1923, 25 commercial vessels transited the Canal. Their aggregate net tonnage was 145,382 tons, and tolls of \$136,604.77 were paid on them. This was a new record day for commercial transits.

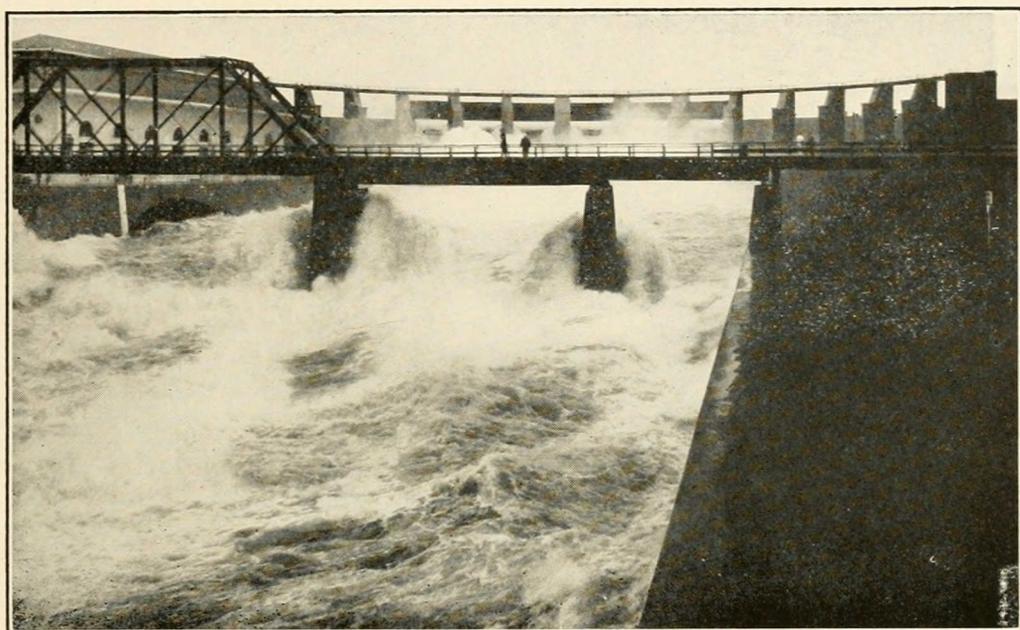
indicated what could be done in an emergency by a force organized to take care of a normal traffic averaging 8 vessels a day.

The water supply available to maintain the summit level of a lock canal at Panama has been the subject of most careful study. During the rainy season, which extends normally through 8 months of the year, we have a surplus of water, but during the dry season, with the normal length of 4 months, the inflow into Gatun Lake is approximately balanced by evaporation alone. The Lake is now our only storage basin. It is filled to elevation 87 at the close of the rainy season, and we draw upon it for lockages, hydroelectric power, and municipal uses, through the year. The intention is not to permit the lake level to fall below 80, which leaves a theoretical depth of 40 feet in the Gaillard Cut. The storage capacity in this top 7 feet is about 32 billion cubic feet. This has proved ample to take care of the present volume of traffic, and it will suffice for several years to come. But as traffic increases it will become necessary to provide for additional storage. The original plans for a lock canal contemplated a dam across the gorge of the Chagres River, at Alhajuela, 10 miles above the point where the river enters the canal prism. We are now proceeding with a contour survey to determine the capacity of the proposed reservoir. It is estimated at 15 billion cubic feet.

Of the total inflow into Gatun Lake under present conditions, amounting last year to 189 billion cubic feet, approximately 10 per cent is lost by evaporation, lockages take 12 per cent, 26 per cent is used by the hydroelectric station at Gatun which supplies power for the operation of the Canal and all of its accessories, and 51 per cent is wasted over the spillway.

A dam at Alhajuela will permit us to conserve a part of the water which is now wasted. It may also prove

advisable to build a hydroelectric station at Alhajuella. Water used there for the generation of power will flow into Gatun Lake, where it will still be available for lockages or power. In the meantime we can reduce the consumption of water for power by transferring during the dry season a part or the whole of the load from the hydroelectric plant at Gatun to the steam plant at Miraflores, which is held in reserve to meet possible breakdowns at Gatun or on the transmission line or an emergency due to extreme dry-season conditions.



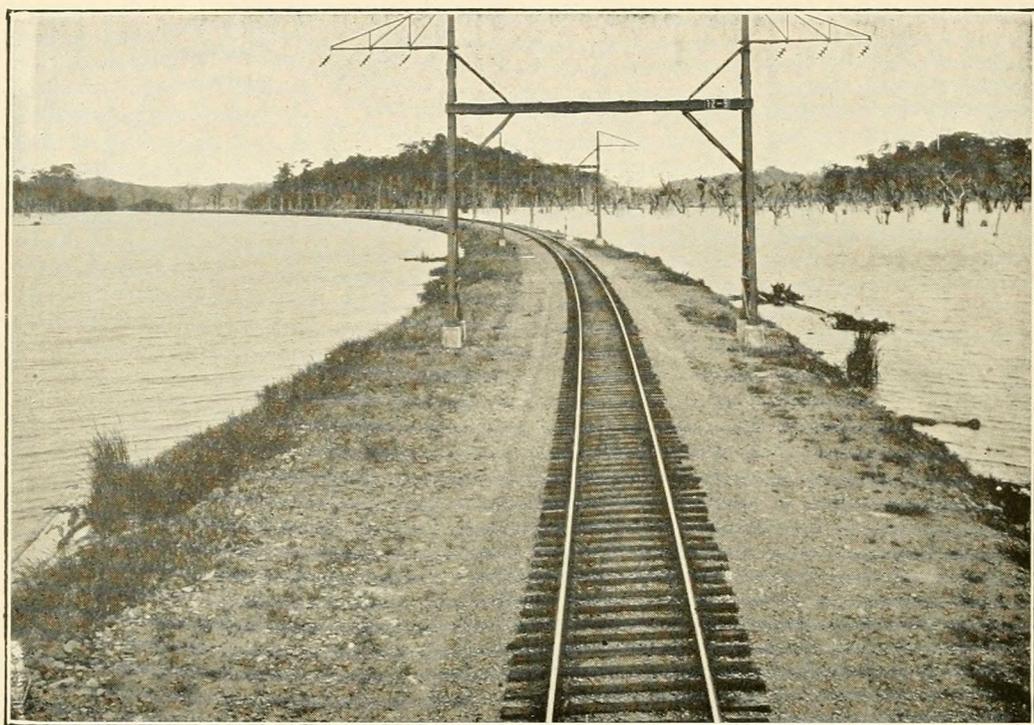
Discharge from Gatun Spillway through 6 gates.

The significant points are that we are now using only 12 per cent of the available inflow for lockages, that the construction of the Alhajuella dam will increase the surplus available during the dry season by approximately 50 per cent, and that, although it is economical now to draw on the Lake for hydroelectric power, this draft can be reduced or, in case of necessity, discontinued during a part of the year.

It is important to note also that this discussion of the water problem is based on a minimum depth of 40 feet through the Gaillard Cut, sufficient to carry any

ship yet constructed. The usefulness of the Canal would be but little impaired if the depth of water were reduced to 35 feet for very brief periods, and the great majority of ships making the transit could pass with even less depth.

Besides the Alhajuela dam there is another project under consideration which will provide additional storage while eliminating a very minor defect to the present Canal.



The reconstructed Panama Railroad passes through a part of Gatun Lake on heavy fills.

When water is drawn from the Lake to fill the Pedro Miguel Lock, which means an average draft of 3,800,000 cubic feet in $7\frac{1}{2}$ minutes, the flow of water through the Cut during the short period that the valves are open is not equal to that required to fill the lock; consequently the water at the lock entrance drops as much as 18 inches, and when the valves close, equalization of level rapidly takes place, followed by an overtravel crest which rises more than a foot above the original level. This surge in its alternate stages of crest and

trough travels the entire length of the Cut and as far as the head of the Chagres Valley arm of the Lake. After a series of oscillations of decreasing intensity the water resumes its original level. The peak phase is experienced at Gamboa at the northern end of the Cut, $8\frac{3}{4}$ miles from Pedro Miguel, approximately 25 minutes after it has developed at the lock.

These surges do not materially interfere with navigation, but if Gatun Lake were at the level of 80 the trough stage would reduce the depth of water in the Cut from 40 feet to about 38.5 feet, and if the Lake were above 87, the maximum under present conditions, the crest stage of a surge would cause an overflow into the bull wheel chambers at Pedro Miguel Locks, of which the strut slot can not be raised above elevation plus 88.125.

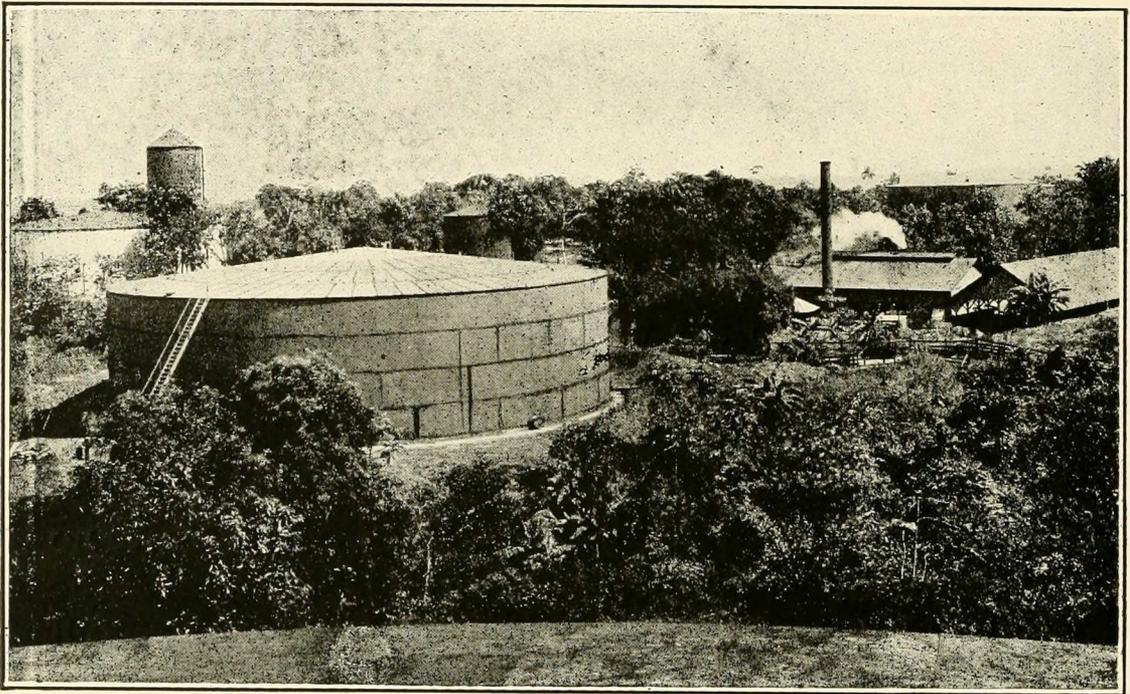
It is proposed to eliminate these surges by constructing a reservoir to the west of the Pedro Miguel Lock with a surface area of about 25 acres, and to draw water for lockages from this reservoir instead of from the Cut. The reservoir itself would in turn be refilled from the Cut, but the flow would be under low head at a rate no faster than 1,200 cubic feet per second. Obviously, the last foot or so of water for filling the lock would still have to be drawn directly from the Cut.

This supplementary construction would practically eliminate the surge and it would be feasible to change the allowable minimum dry-season level to 79 instead of 80, and the maximum elevation can be raised from 87 to 87.5, or possibly a few inches higher. This will provide about 7 billion cubic feet of additional storage. It is likely that this project can be installed for some such sum as \$1,000,000.

A conservative estimate of the lockage capacity of the present locks, allowing the periodical unwatering of one flight for painting and repairs, is 50,000,000 net tons

of shipping per annum, or over four times the present volume of traffic. Careful studies indicate that after the construction of the Alhajuela dam, and with either a hydroelectric plant at Alhajuela or a reserve steam plant to conserve water during the dry season, there will be sufficient water to take care of this maximum volume of traffic even under extreme dry-season conditions.

While any computation of the future growth of traffic is subject to error, it is believed that the 50,000,000-ton mark will not be exceeded before 1955. In other



Oil tanks and pumping station at Mount Hope.

words, the present Canal should prove adequate to meet the demands that will be made upon it for a period of about 30 years. Beyond that it is futile to prophesy. It can be stated, however, that there are no insuperable engineering difficulties that would prevent the construction of 6 more locks, which can be undertaken and completed in time to meet the demands of commerce.

The World War had far-reaching effects on Canal traffic. Following its outbreak in 1914, German shipping, which, after that of Great Britain, was the most

important factor in maritime trade, disappeared from the seas. British shipping was commandeered for the transportation of troops and supplies and for auxiliary naval service, and neutral shipping was gradually diverted by reason of advancing freight rates into war trade in the North Atlantic and Mediterranean. The old trade routes were disorganized, and many countries which might have contributed a substantial tonnage to the Canal, notably those on the west coast of Central and South America, were so paralyzed by the loss of their European markets that their foreign commerce shrank for the time being to negligible dimensions. As the war progressed, this was offset to a certain extent by the development of special war trades, for instance, the resumption of nitrate shipments from Chile for the manufacture of explosives. But it is certain that the war and post-war conditions have greatly retarded the normal expansion of Canal traffic.

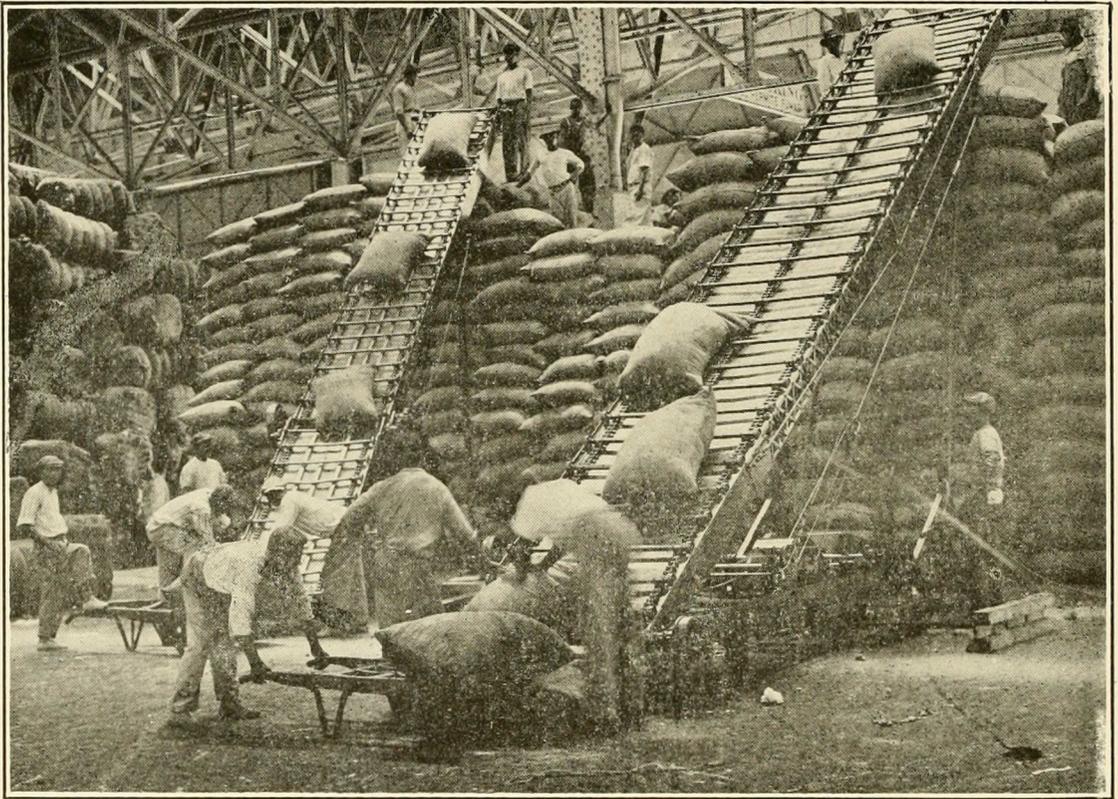
In spite of the adverse conditions of the past decade, the net tonnage of vessels using the new waterway has increased from less than 4,000,000 tons, in 1915, to more than 11,000,000 tons, in 1922, and will almost certainly pass 13,000,000 tons in 1923.

Of the 15,835 commercial vessels which passed through the Canal prior to July 1, 1922, 37 per cent were under the American flag, and 35 per cent were under the British flag. The Norwegians came third with a little more than 6 per cent, and the Japanese fourth with a fraction over 4 per cent. During the past 3 years the Japanese have occupied third place, and their trade through the Canal is growing rapidly. Vessels of 28 other nations have used the Panama route.

The most important trade through the Canal at present is that between the two seaboard of the United States. In terms of cargo it represented, in the fiscal

year 1922, 23.5 per cent of the total, and it is growing very rapidly, in part, no doubt, at the expense of our transcontinental railroads.

The next in order of importance is that between the Atlantic and Gulf ports of the United States and the Far East, representing 18.6 per cent of the total. In third place is the trade between the west coast of the United States and Europe, representing 13.6 per cent



Portable cargo conveyors used on piers.

of the total. The trade of the United States and Europe with the west coast of South America was an important fraction of the whole during and immediately after the war, but it has declined in the last 2 years, due to the slump in Chilean nitrate exports and a slack demand for other South American products. This section, however, as it develops, will undoubtedly provide a heavy volume of traffic in the future.

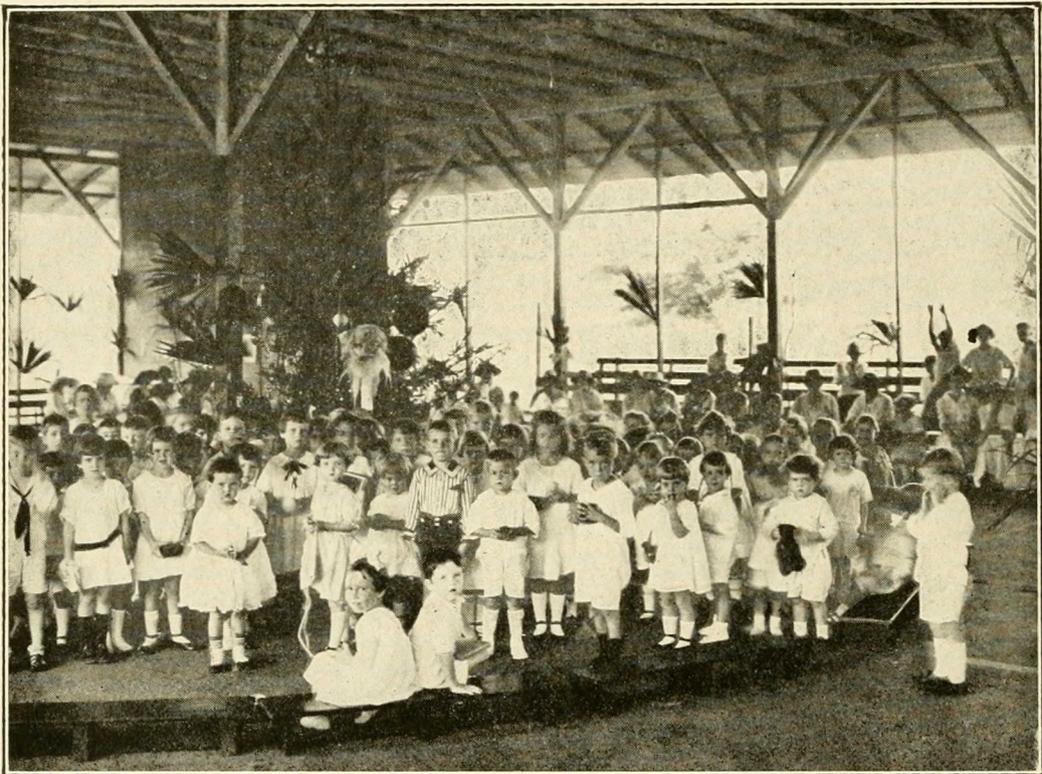
Of the westbound cargo moving through the Canal in 1922, 68.6 per cent was shipped from our Atlantic

ports, and of the eastbound cargo 53.2 per cent was shipped from our Pacific ports. While the Canal is open to the world and is used by all maritime nations, it is of paramount importance to our own country.

A discussion of The Panama Canal from any angle would be incomplete without some reference to the men who built it and are operating it to-day. From the beginning, the job was one which appealed to the imagination, and it attracted and held Americans of a high type, who felt that they were working not only for themselves but for their country and for the world. The pioneers of 1904 and 1905 assumed the risk of death by disease and the certainty of discomfort and privation in an undeveloped tropical country. But even in those early days the morale of the force was excellent. When Colonel Goethals arrived on the Isthmus, in the spring of 1907, he found an organization assembled by his predecessor, Mr. John F. Stevens, which was enthusiastic and efficient. Its loyalty was largely personal; every man on the job was a devoted admirer of Mr. Stevens and suspicious of the new administration. Colonel Goethals' first important task was to persuade these men, whose attitude at the outset was distinctly hostile, that he was determined and competent to carry on the work of his able predecessor. He soon won their entire devotion, and, starting with the nucleus he found on the Isthmus, he built up an organization as remarkable as the work it was accomplishing. His ability to judge and handle men was perhaps his most valuable asset and a factor of supreme importance in the successful completion of the Canal. Although a hard taskmaster, he was invariably and inflexibly just, and patient where he could discover good intentions. Toward the close of his long administration, the admiration accorded to him by his subordinates assumed the proportions of a cult.

The tradition of the construction days has been carried over into the period of operation. Many of the men now on the Isthmus served under Stevens and Goethals, and the newcomers have caught their spirit.

The conditions of life have gradually changed. The construction camps have been replaced by permanent towns, the more adventurous spirits have either drifted away to other jobs or else been tamed by the years, and instead of a shifting force of young,



Scene at Balboa Playground.

unmarried men, we have a more normal population that includes as many dependent women and children as a community in the United States. What was originally an expeditionary force has become a permanent colony.

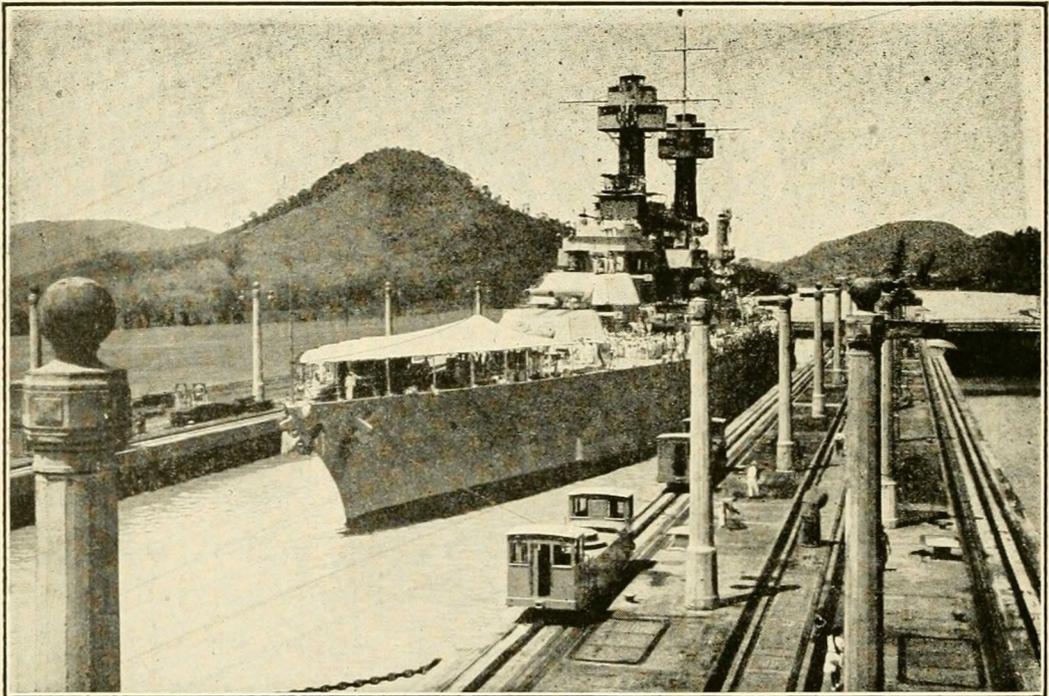
Occasionally at the crossroads we meet distinguished travelers. Three Presidents have inspected the Canal, and among the thousands of visitors we have seen many whose work in the world has made them international figures.

The Canal community is one of typical Americans living according to American traditions and American standards. Their patriotism is beyond question. During the late war 421 employees of The Panama Canal enlisted for active service. The number would have been greater if it had been possible to release all who wanted to go, but the operation of the Canal itself was an important war service that could not be impaired, and many were held because it was known that they could best serve the country by remaining at their usual posts. All of the drives for the Red Cross and for the sale of bonds went over the top in the Canal Zone. Of Canal employes who followed the flag, 11 gave their lives. On the last anniversary of the armistice we unveiled, at Balboa Heights, a tablet in their honor in a beautiful and impressive service and at a point which seemed designed for such use.

A proper question, and one which comes up in any discussion concerning the Canal, can be put in the popular phrase: "Does it pay?" I should answer this from three points of view: First, as a commercial investment; second, as an investment in national defense; and third, as an investment in national prestige, and in each case I would answer unhesitatingly: "Yes, it is paying and will pay more handsomely as the years go on."

In round numbers, the Canal has cost our Government \$375,000,000. As I have indicated, a large proportion of this expenditure was made on the basis of probable use for national defense. By direction of Secretary Weeks we have made a study to determine what part of the total expenditure should be considered as national defense and what should be considered as the proper cost of the Canal as a commercial undertaking. The figures that were arrived at and approved for accounting purposes were \$246,000,000, as representing the commercial investment in the Canal itself

and \$28,000,000, as invested in auxiliary business enterprises. On this basis the Canal accounts are now set up, each separate account having its independent capitalization. Upon the ability of each separate unit of auxiliary business to prove its commercial worth will depend its continuance in operation. Amortization is provided for on the basis of various periods ranging from 10 to 100 years, according to the life of the unit in which we have made the investment. It is gratifying



U. S. S. *Maryland* in Pedro Miguel Locks—February, 1923.

to be able to tell you that the receipts for last October came very close to paying all the expenses of operation, maintenance, amortization, and interest at 3 per cent on the investment. November tolls slightly exceeded October and the result will probably show about the same. December tolls exceeded either of these two months by about \$50,000.* These months were months of extraordinarily high tolls receipts, topping the receipts of any month prior to October by over \$150,000 and in December by \$200,000, and it would be foolish

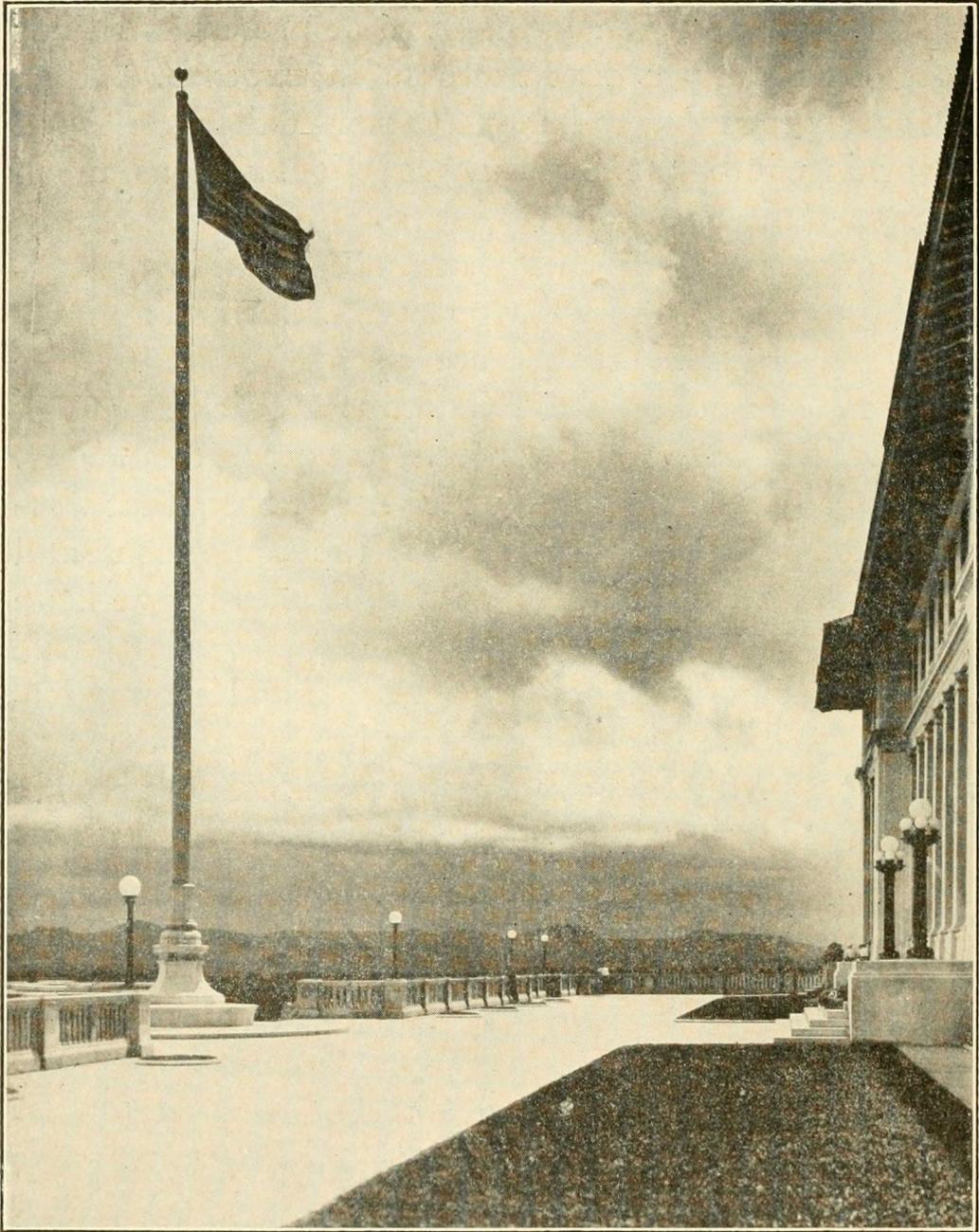
*Tolls for January were \$192,715 more than December. Tolls for February, 1923 (a 28-day month) were \$1,423,954; for March, \$1,827,718.44; April, \$1,878,938.15; May, \$1,972,216.04; June \$1,898,043.80.

to predict that receipts for every month in the immediate future will reach these figures. But, as world commerce gets back to normalcy, the receipts for these now record months will seem small. You should, also, bear in mind that our expenditures will not increase in the same proportion as the traffic. We could probably handle twice as much business as at present with not more than 20 per cent increase in expense. It is, however, gratifying to be able to report that the Canal is turning into the Treasury about twice as much money as it is taking out.

As a factor in national defense the Canal is a profitable investment. Experts who have studied its military and international aspects are in agreement on the inestimable benefits of the Canal as a quick means of transferring our ships of war from one ocean to another. It is entirely possible that but for the nitrates that were carried rapidly from Chile to the American and European factories in 1916-1918 the Allies might have lost the World War.

As a matter of national prestige the Canal is a wonderful investment. I realize that it is impracticable for an engineer to evaluate an item that goes into an account so intangible as national prestige, and yet we all recognize that such accounts may be of surpassing value. The Canal and the community connected with its operation are the finest expressions of American thoroughness in engineering, public health, and community life that I have ever known, and certainly they compare highly in these respects with the work of any other nation. Engineers come from everywhere to study our engineering work. Sanitarians have come from both the British and Dutch East Indies, from Japan and from all parts of Latin America to study our public-health work. The United Fruit Company, the Guggenheims, the Standard Oil, and other American

corporations operating in the tropics, have benefitted by our errors as well as by our successes. In every part of Latin America, when a question arises as to American thoroughness and skill comes the answer: "The Panama Canal."

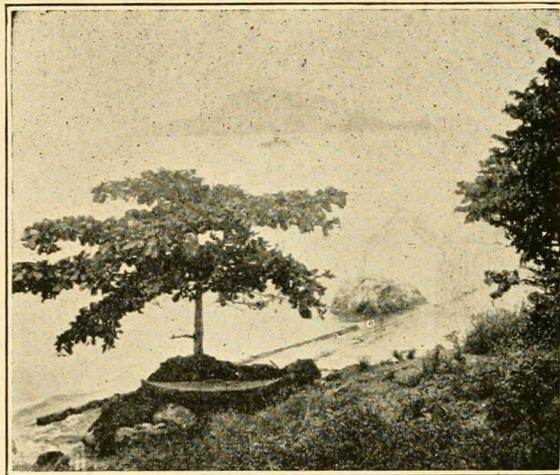


Administration Building, Balboa Heights.

If you agree with me that The Panama Canal, both in construction and operation reflects credit on American genius and furnishes at least one example of successful

business operation by the Government, you will probably also agree as to these, the reasons therefor. In the construction days American genius for initiative, organization, and indomitable energy, exemplified in the persons of Roosevelt, Goethals, and Gorgas, insured success. Another great help was the absolute divorce from the bane of political appointments. Another, as construction days neared their close, the builders of the Canal devised the form of government as I have briefly outlined it, and it has been permitted to remain as designed. Congresses, Secretaries of War, and Presidents have stood behind my predecessors and myself in resisting efforts to change the scheme which has worked so well. We enjoy two privileges not granted to any other governmental operation, the loss of either of which would at once ruin our efficiency: We are relieved from the blight of fiscal year limitation; in other words, an appropriation remains available until expended. This enables us to set up reserves for replacement and repairs and, in an emergency, to proceed with major repairs or entire replacement of large items of plant without having to wait 2 years or more for an appropriation. The other exceptional exemption is the retention of the legal authority to use over and over as a revolving fund the moneys received from the Canal's business operations. Our tolls collections go direct to the Treasury, but funds appropriated for the operation, sanitation, or government may be used several times over with an annual remittance of profits to the United States Treasury. Congress has left us these two privileges, recognizing the fact that we can not otherwise operate a big business in a business-like way. And, finally, one reason for our success so far is one which should impress you gentlemen strongly, and that is that all the Governors of the Canal have been engineers. No member of any other pro-

fession can possibly be so well qualified to deal with the many major problems arising from operation and maintenance and, at the same time, to keep the entire operating force keyed up to the doctrine that the mission of the Canal is service to the ships, and that all other functions must be bent or broken to fit that doctrine.



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