Official Handbook

of

The Panama Canal

FOURTH EDITION—FINAL REVISION.

COMPILED BY

THE SECRETARY OF THE ISTHMIAN CANAL COMMISSION

Ancon, Canal Zone

1913

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

Panama Canal

Official Handbook

Ancon, Canal Zone

1913

Length from deep water to deep water (miles)	50
Length from shore line to shore line (miles)	40
Bottom width of channel, maximum (feet)	1,000
Bottom width of channel, minimum, 9 miles, in Culebra Cut (feet)	300
Locks, in pairs	12
Locks, usable length (feet)	1,000
Locks, usable width (feet)	110
Gatun Lake, area (square miles)	164
Gatun Lake, channel depth (feet)	85 to 45
Culebra Cut, channel depth (feet)	45
Excavation, Canal Proper, estimated total (cubic yards)	209,668,000
Excavation, Permanent Structures, including terminals, estimated (cubic yards)	22,685,000
Excavation, grand total, estimated (cubic yards)	232,353,000
Excavation, Due to Slides and Breaks, estimated (cubic yards) about	25,000,000
Excavation accomplished October 1, 1913, (cubic yards)	211,048,198
Excavation, Remaining, Canal Proper, October 1, 1913, (cubic yards)	21,304,802
Excavation by the French (cubic yards)	78,146,960
Excavation by French, useful to present Canal, (cubic yards)	29,908,000
Excavation by French, estimated value to Canal	$25,389,240
Value of all French property	$42,799,826
Concrete, total estimated for Canal (cubic yards)	5,208,800
Time of transit through completed Canal (hours)	10 to 12
Time of passage through locks (hours)	3
Relocated Panama Railroad, total cost	$8,866,392.02
Relocated Panama Railroad, length (miles)	47.11
Canal Zone, area (square miles)	436
Canal and Panama Railroad force actually at work in September, 1913 (about)	37,000
Canal and Panama Railroad force, Americans in September, 1913 (about)	5,000
Cost of Canal, estimated total	$375,000,000
Work begun by Americans	May 4, 1904
Date of official opening	Jan. 1, 1915

THE Panama Canal does not, as is quite generally thought, cross the Isthmus from east to west. As is shown on the accompanying map, its general direction is from northwest to southeast, the Pacific entrance near Panama being about 22½ miles east of the Atlantic entrance near Colon. It is a lake canal as well as a lock canal, its dominating feature being Gatun Lake, a great body of water covering about 164 square miles and occupying the northern half of that portion of the Isthmus through which the Canal passes. This lake is an elevated body of water with a surface level maintained at from 85 to 87 feet above sealevel by the Gatun Dam and locks on the Atlantic side and the Pedro Miguel Locks and Dam on the Pacific side. (Plate A.) The Culebra Cut is really an arm of the lake. On both Atlantic and Pacific sides there is an approach channel, which is an inlet of the sea, extending from deep water in the sea up to the foot of the locks which lift vessels to the level of the lake through which they are to pass.

The entire length of the Canal from deep water in the Atlantic to deep water in the Pacific is about 50 miles. Its length from shore line to shore line is about 40 miles. In passing through it from the Atlantic to the Pacific, a vessel will enter the approach channel in Limon Bay, which has a bottom width of 500 feet and extends to Gatun, a distance of about 7 miles. At Gatun it will enter a series of three locks in flight and be lifted 85 feet to the level of Gatun Lake. It may steam at full speed through this lake, in a channel varying from 1,000 to 500 feet in width, for a distance of about 24 miles, to Gamboa, where it will enter the Culebra Cut. It will pass through the Cut, a distance of about 9 miles, in a channel with a bottom width of 300 feet, to Pedro Miguel. There it will enter a lock and be lowered 30⅓ feet to a small lake, at an elevation of 54⅔ feet above sealevel, and will pass through this for about 1½ miles to Miraflores. There it will enter two locks in series and be lowered to sealevel, passing out into the Pacific through a channel about 8½ miles in length, with a bottom width of 500 feet. The depth of the approach channel on the Atlantic side, where the maximum tidal oscillation is 2½ feet, is 41 feet at

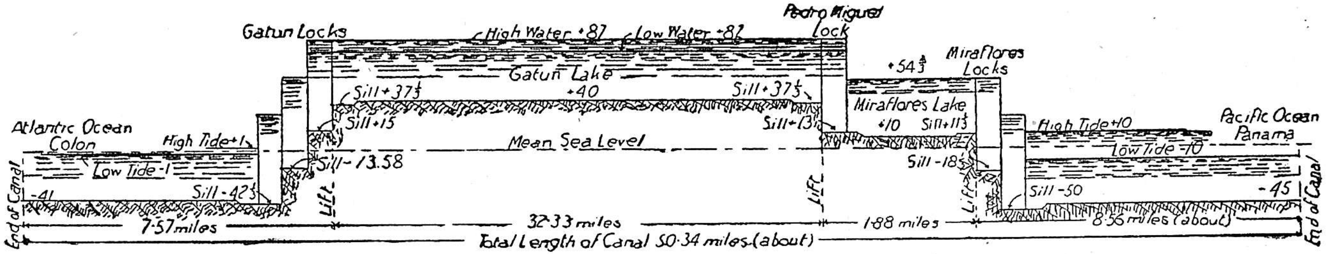


PLATE A—DIAGRAM SHOWING LAKE ELEVATION

mean tide, and on the Pacific side, where the maximum oscillation is 21 feet, the depth is 45 feet at mean tide. The mean sealevel in both oceans is the same.

Throughout the first 15 miles from Gatun, the width of the Lake channel is 1,000 feet; then for 4 miles it is 800 feet, and for 4 miles more, to the northern entrance of Culebra Cut at Gamboa, it is 500 feet. The depth will vary from 87 to 45 feet. The water level in the Cut will be that of the Lake, the depth 45 to 47 feet.

Three hundred feet is the minimum bottom width of the Canal. This width begins about half a mile above Pedro Miguel Locks and extends about 8 miles through Culebra Cut, with the exception that at all angles the channel is widened sufficiently to allow a thousand-foot vessel to make the turn. The Cut has eight angles, or about one to every mile. The 300-foot widths are only on tangents between the turning basins at the angles. The smallest of these angles is 7° 36′, and the largest 30°.

In the whole Canal there are 22 angles, the total curvature being 600° 51′. Of this curvature, 281° 10′ are measured to the right, going south, and 319° 41′ to the left. The sharpest curve occurs at Tabernilla, and is 67° 10′.

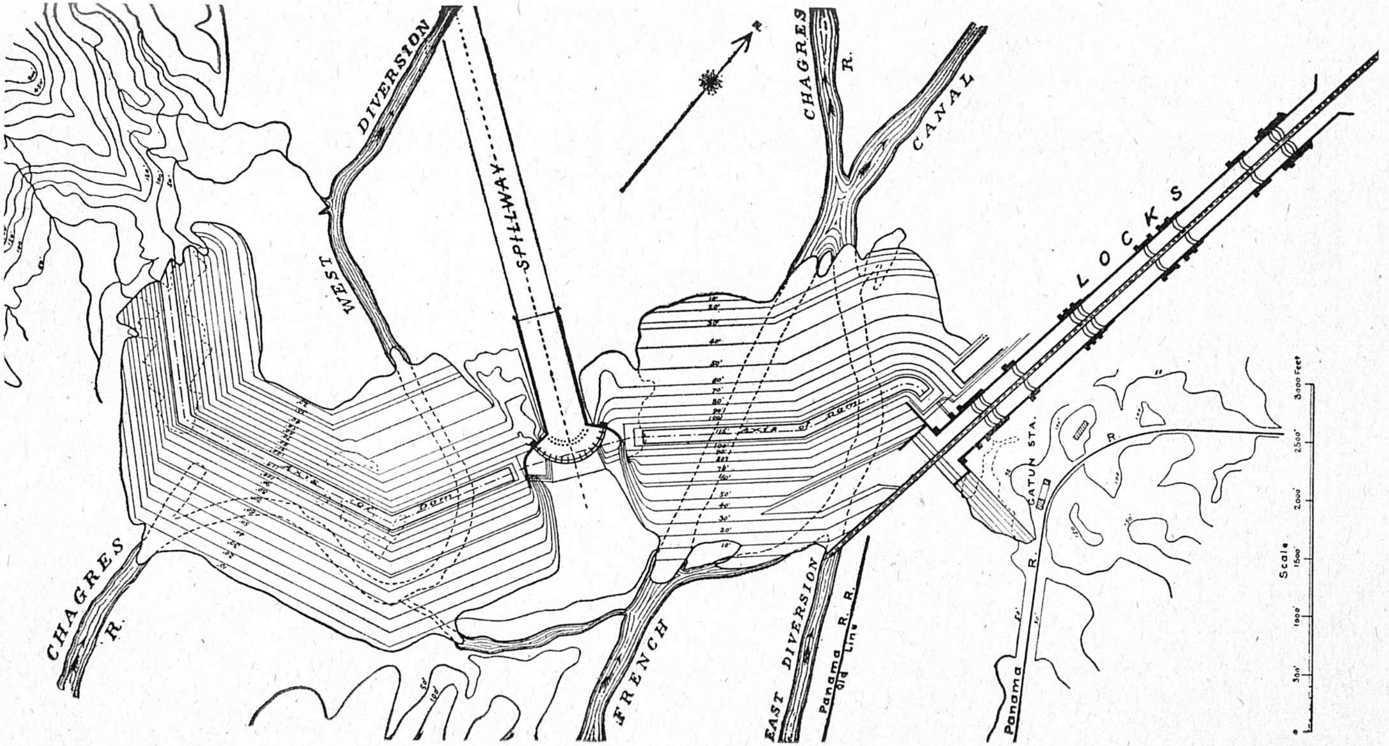


PLATE B.—GATUN DAM, SPILLWAY, AND LOCKS

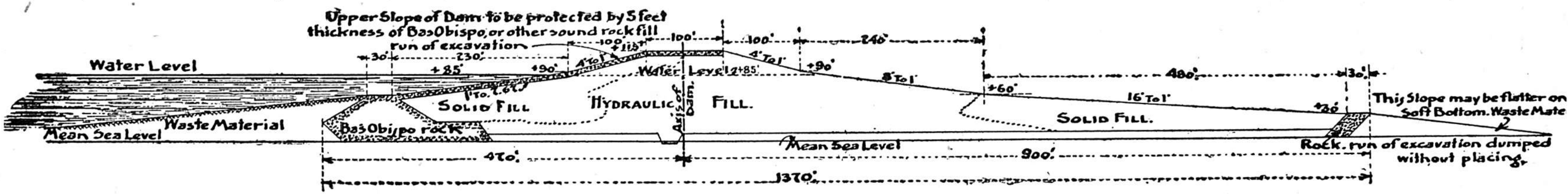


PLATE C—CROSS SECTION GATUN DAM

E MR 31088—2

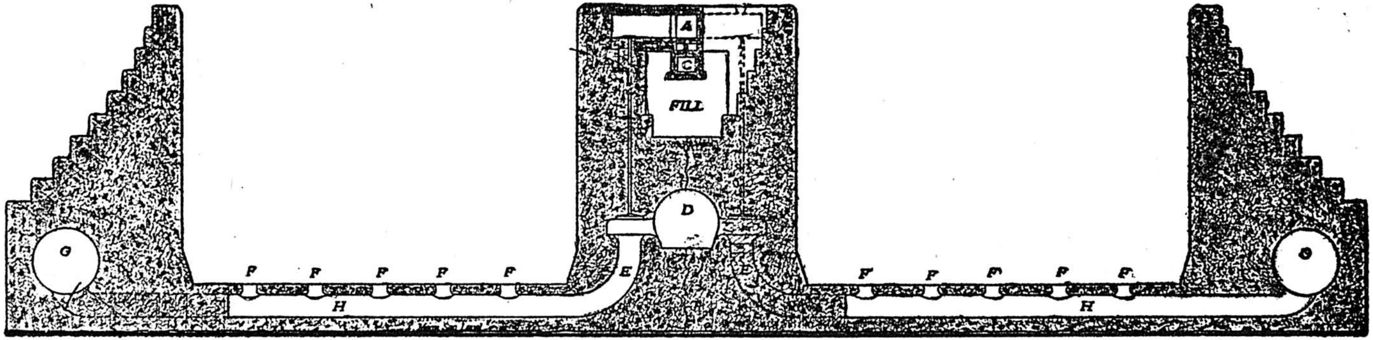
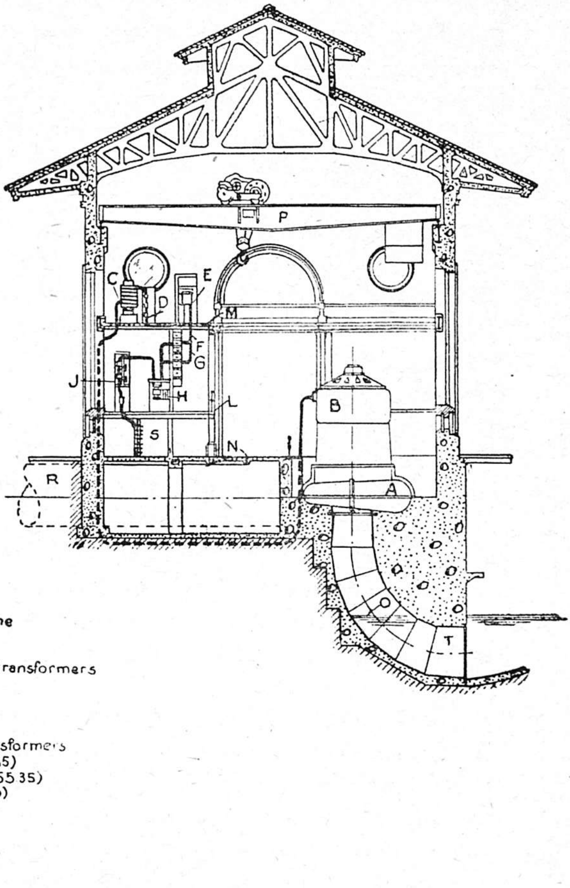


PLATE D—CROSS SECTION OF LOCK CHAMBERS AND WALLS OF LOCKS

A—Passageway for operators.
B—Gallery for electric wires.
C—Drainage gallery.
D—Culverts in center walls.
E—These culverts run under the lock floor and alternate with those from side walls.
F—Wells opening into lateral culverts into lock chambers.
G—Culverts in side walls.
H—Lateral culverts.

The Gatun Dam, which forms Gatun Lake by impounding the waters of the Chagres and its tributaries, is nearly $1\frac{1}{2}$ miles long, measured on its crest, nearly $\frac{1}{2}$ mile wide at its base, about 400 feet wide at the water surface, about 100 feet wide at the top, and its crest has an elevation of 105 feet above mean sealevel, or 20 feet above the normal level of the Lake. It is in reality a low ridge uniting the high hills on either side of the lower end of the Chagres Valley so as to convert the valley into a huge reservoir. Of the total length of the Dam only 500 feet, or one-fifteenth, is exposed to the maximum water head of 85 to 87 feet. The interior of the Dam is formed of a natural mixture of sand and clay, dredged by hydraulic process from pits above and below the Dam, and placed between two large masses of rock and miscellaneous material obtained from steamshovel excavation at various points along the Canal. The top and upstream slope are thoroughly riprapped. The entire Dam contains about 21,000,000 cubic yards of material. (Plates B and C.)

The Spillway is a concrete-lined channel 1,200 feet long and 285 feet wide cut through a hill of rock nearly in the center of the Dam, the bottom being 10 feet above sealevel at the upstream end and sloping to sealevel at the toe. Across the upstream or lake opening of this channel a concrete dam has been built in the form of an arc of a circle making its length 808 feet although it closes a channel with a width of only 285 feet. The crest of the dam is 69 feet above sealevel, or 16 feet below the normal level of the lake which is 85 feet above sealevel. On the top of this dam there are 13 concrete piers with their tops 115.5 feet above sealevel, and between these there are mounted regulating gates of the Stoney type. Each gate is of steel sheathing on a framework of girders and moves up and down on roller trains in niches in the piers. They are equipped with sealing devices to make them watertight. Machines for moving the gates are designed to raise or lower them in approximately ten minutes. The highest level to which it is intended to allow the lake to rise is 87 feet above sealevel, and it is probable that this level will be maintained continuously during wet seasons. With the lake at that elevation, the regulation gates will permit of a discharge of water greater than the maximum known discharge of the Chagres River during a flood.



A- 2,250 k. w. water turbine
B- 2,000 k. w. generator
C- Reactance
D- Generator instrument transformers
E- Generator switches
F- Bus 1
G- Bus 2.
H- Circuit switches
J- Circuit instrument transformers
L- First gallery (el. + 40.85)
M- Second gallery (el. + 55.35)
N- Main floor (el. + 33.25)
O- Low water (el. + 7)
P- 30 ton crane.
R- Penstock.
S- Cable Vault.
T- Draft Tube.

PLATE E—HYDROELECTRIC STATION

Adjacent to the north wall of the spillway is located a hydroelectric station capable of generating through turbines 6,000 kilowatts for the operation of the lock machinery, machine shops, dry dock, coal-handling plant, batteries, and for the lighting of the locks and Zone towns and, if desirable, operating the Panama railroad. The building is constructed of concrete and steel, and of a design suitable for a permanent power house in a tropical country. The dimensions are such as to permit the installation of three 2,000-kilowatt units, and provision is made for a future extension of three additional similar units. It is rectangular in shape, and contains one main operating floor, with a turbine pit and two galleries for electrical equipment. The building, with the machinery and electrical equipment, is laid out upon the unit principle, each unit consisting of an individual headgate, penstock, governor, exciter, oil-switch, and control panel.

Water is taken from Gatun Lake, the elevation of which will vary with the seasons from 80 to 87 feet above sealevel, through a forebay constructed as an integral part of the curved portion of the north spillway approach wall. From the forebay the water is carried to the turbines through three steel plate penstocks, each having an average length of 350 feet. The entrances are closed by cast iron headgates and bar iron trash racks. The headgates are raised and lowered by individual motors geared to rising stems attached to the gate castings. The driving machinery and the motors are housed in a small concrete gatehouse erected upon the forebay wall directly over the gate recesses and trash racks. The gatehouse is constructed for the present requirements of three headgates, and provision will be made for a future addition of three more units. (Plate E.)

Gatun Lake impounds the waters of a basin comprising 1,320 square miles. (*See Map.*) When the surface of the water is at 85 feet above sealevel, the lake has an area of about 164 square miles, and contains about 183 billion cubic feet of water. During eight or nine months of the year, the lake is kept constantly full by the prevailing rains, and consequently a surplus needs to be stored for only three or four months of the dry season. The smallest run-off of water in the basin during the past 22 years, as measured at Gatun, was that of the fiscal year, 1912, which was about 132 billion cubic feet. Previous to that year the smallest run-off of record was 146 billion cubic feet. In 1910, the run-off was 360 billion cubic feet, or a sufficient quantity to fill the lake one and a half times. The low record of 1912 is of interest as showing the effect which a similar dry season, occurring after the opening of the Canal, would have upon its capacity for navigation. Assuming that the Gatun Lake was at elevation plus 87 at the beginning of the dry season on December 1, and that the hydroelectric plant at the Gatun Spillway was in continuous operation, and that 48 lockages a day were being made, the elevation of the lake would be reduced to its lowest point, plus 79.5, on May 7, at the close of the dry season, after which it would continuously rise. With the water at plus 79 in Gatun Lake there would be 39 feet of water in Culebra Cut, which would be ample for navigation. The water surface of the lake will be maintained during the rainy season at 87 feet above sealevel, making the minimum channel depth in the Canal 47 feet. As navigation can be carried on with about 39 feet of water, there will be stored for the dry season surplus over 7 feet of water. Making due allowance for evaporation, seepage, leakage at the gates, and power consumption, this would be ample for 41 passages daily through the locks, using them at full length, or about 58 lockages a day when partial length is used, as would be usually the case, and when cross filling from one lock to the other through the central wall is employed. This would be a larger number of lockages than would be possible in a single day. The average number of lockages through the Sault Ste.

Marie Canal on the American side was 41.7 per day in the season of navigation of 1912, which was about eight months long. The average number of ships passed was about 1½ per lockage. The total number of vessels was 14,916, registering 30,947,133 net tons. The Suez Canal passed 5,373 vessels in 1912, about 12 per day, with a total tonnage of 20,275,120. The total receipts were $27,300,000, the largest in the history of the canal.

The water level of Gatun Lake, extending through the Culebra Cut, is maintained at the south end by an earth dam connecting the locks at Pedro Miguel with the high ground to the westward, about 1,400 feet long, with its crest at an elevation of 105 feet above mean tide. A concrete core wall, containing about 700 cubic yards, connects the locks with the hills to the eastward; this core wall rests directly on the rock surface and is designed to prevent percolation through the earth, the surface of which is above the Lake level.

A small lake between the locks at Pedro Miguel and Miraflores is formed by dams connecting the walls of Miraflores locks with the high ground on either side. The dam to the westward is of earth, about 2,700 feet long, having its crest about 15 feet above the water in Miraflores Lake. The east dam is of concrete containing about 75,000 cubic yards; is about 500 feet long, and forms a spillway for Miraflores Lake, with crest gates similar to those at the Spillway of the Gatun Dam. The Rio Grande and five of its tributaries empty into the lake. A secondary use of the lake is as a water supply for the Canal villages on the southern slope of the continental divide and the city of Panama. A pumping station and filtration plant, with a capacity of 15,000,000 gallons daily, is placed on the east side of the lake.

There are 6 double locks in the Canal; three pairs in flight at Gatun, with a combined lift of 85 feet; one pair at Pedro Miguel, with a lift of 30⅓ feet, and two pairs at Miraflores, with a combined lift of 54⅔ feet at mean tide. The usable dimensions of all are the same—a length of 1,000 feet, and width of 110 feet. Each lock is a chamber, with walls and floor of concrete, and mitering gates at each end.

The side walls are 45 to 50 feet wide at the surface of the floor; are perpendicular on the face, and narrow from a point 24⅓ feet above the floor until they are 8 feet wide at the top. The middle wall is 60 feet wide, approximately 81 feet high, and each face is vertical. At a point 42⅓ feet above the surface of the floor, and 15 feet above the top of the middle culvert, this wall divides into two parts, leaving a space down the center much like the letter "U," which is 19 feet wide at the bottom and 44 feet wide at the top. In this center space is a tunnel divided into three stories, or galleries. The lowest gallery is for drainage; the middle, for the wires that carry the electric current to operate the gate and valve machinery installed in the center wall, and the upper is a passageway for the operators. (Plate D.)

The lock gates are steel structures seven feet thick, 65 feet long, and from 47 to 82 feet high. They weigh from 390 to 730 tons each. Ninety-two leaves are required for the entire Canal, the total weighing 60,000 tons. The leaves are shells of structural steel covered with a sheathing of steel riveted to the girder framework. Each leaf is divided horizontally into two separate compartments. The lower compartment is watertight, for the purpose of making the leaf so buoyant that it will practically float in the water and thus largely relieve the stress upon the bearings by which it is hinged to the wall. This watertight compartment is subdivided vertically into three sections, each independently watertight so that if the shell should be broken in any way or begin to leak, only one section would probably be affected. An air shaft 26 inches in diameter runs from the bottom compartment up to the top of the gate, and this also is watertight where it passes through the upper half of the leaf.

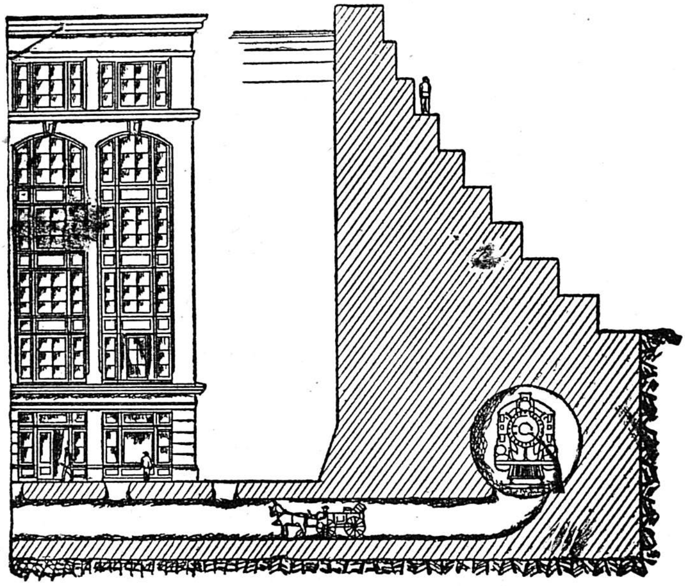


PLATE F—SIDE WALL OF LOCKS COMPARED WITH SIX-STORY BUILDING

Intermediate gates are used in all except one pair of the locks, in order to save water and time, if desired, in locking small vessels through, the gates being so placed as to divide the locks into chambers 600 and 400 feet long, respectively. Ninety-five per cent of the vessels navigating the high seas are less than 600 feet long.

The highest gates and the highest lock walls on the Canal are those of the lower locks at Miraflores, and these locks are the only ones which have no intermediate gates. The total lift from mean sealevel to the level of Miraflores Lake, $54\frac{2}{3}$ feet, is equally divided between the upper and lower locks, and under ordinary conditions, all should be of equal volume. The waters of the Pacific, however, extend into the lower locks, and the range of tide is from 10 feet below to 10 feet above mean sealevel. Furthermore, the area of the upper locks is greater than the lower, because of the omission of the intermediate gates in the latter. The combined result is that the volume of each lower lock is less than that of the upper when the tide is higher than about two feet below mean tide, and the lock is incapable of receiving the full contents of an entire upper lock without causing an overflow of the walls and gates. A portion of the water from an upper lock must be wasted through the culverts or cross-emptied into the twin lock. To diminish this waste as much as practicable, the volume of the lower locks has been enlarged by increasing the height of the walls and gates to 82 feet which is the maximum consistent with economy and safety in construction.

In the construction of the locks, there were used approximately 4,500,000 cubic yards of concrete, requiring about the same number of barrels of cement.

The locks are filled and emptied through a system of culverts. One culvert 254 square feet in area of cross section, about the area of the Hudson River tunnels of the Pennsylvania railroad, (Plate F.) extends the entire length of each of the middle and side walls and from each of the large culverts, there are several smaller culverts 33 to 44 square feet in area, which extend under the floor of the lock and communicate with the lock chamber through holes in the floor. The large culverts are controlled at points near the miter gates by large valves and each of the small culverts extending from the middle wall feeds in both directions through laterals, thus permitting the passage of water from one twin lock to another, effecting a saving of water. (Plate D.)

To fill a lock the valves at the upper end are opened and the lower valves closed. The water flows from the upper pool through the large culverts into the small lateral culverts and thence through the holes in the floor into the lock chamber. To empty a lock the valves at the upper end are closed and those at the lower end are opened and the water flows into the lower lock or pool in a similar manner. This system distributes the water as evenly as possible over the entire horizontal area of the locks and reduces the disturbance in the chamber when it is being filled or emptied. (See also "Electric Control of Lock Machinery" p. 24.)

The depth of water over the miter sills of the locks is 40 feet in salt water and $41\frac{1}{3}$ feet in fresh water.

The average time in filling and emptying a lock is about fifteen minutes, without opening the valves so suddenly as to create disturbing currents in the locks or approaches. The time required to pass a vessel through all the locks is estimated at 3 hours; one hour and a half in the three locks at Gatun, and about the same time in the three locks on the Pacific side. The time of passage of a vessel through the entire Canal is estimated as ranging from 10 to 12 hours, according to the size of the ship, and the rate of speed at which it can travel.

The machinery for opening and closing the miter gates was invented in the office of the Assistant Chief Engineer by Edward Schildhauer, Electrical and Mechanical Engineer, and a patent has been issued on it. It is the subject of the illustration herewith. (Plate G.) It consists essentially of a crank gear, to which is fastened one end of a strut or connecting rod, the other end of which is fastened to a lock gate. The wheel moving through an arc of 197 degrees, closes or opens the gate leaf, according to the direction in which it is turned. One operation takes 2 minutes. The crank gear is a combination of gear and crank, is constructed of cast steel, is 19 feet 2 inches in diameter, and weighs approximately 35,000 pounds. It is mounted in a horizontal position on the lock wall, turns on a large center pin, and is supported at the rim in four places by rollers. The center pin is keyed into a heavy casting anchored securely to the concrete. The crank-gear has gear teeth on its rim and is driven through a train of gears and pinions by an electric motor in a contiguous room. The motor is remotely controlled by an operator who is stationed at a central control house near the lower end of the upper locks. A simple pull of a small switch is sufficient to either close or open a 700-ton gate, the operation being perfectly automatic.

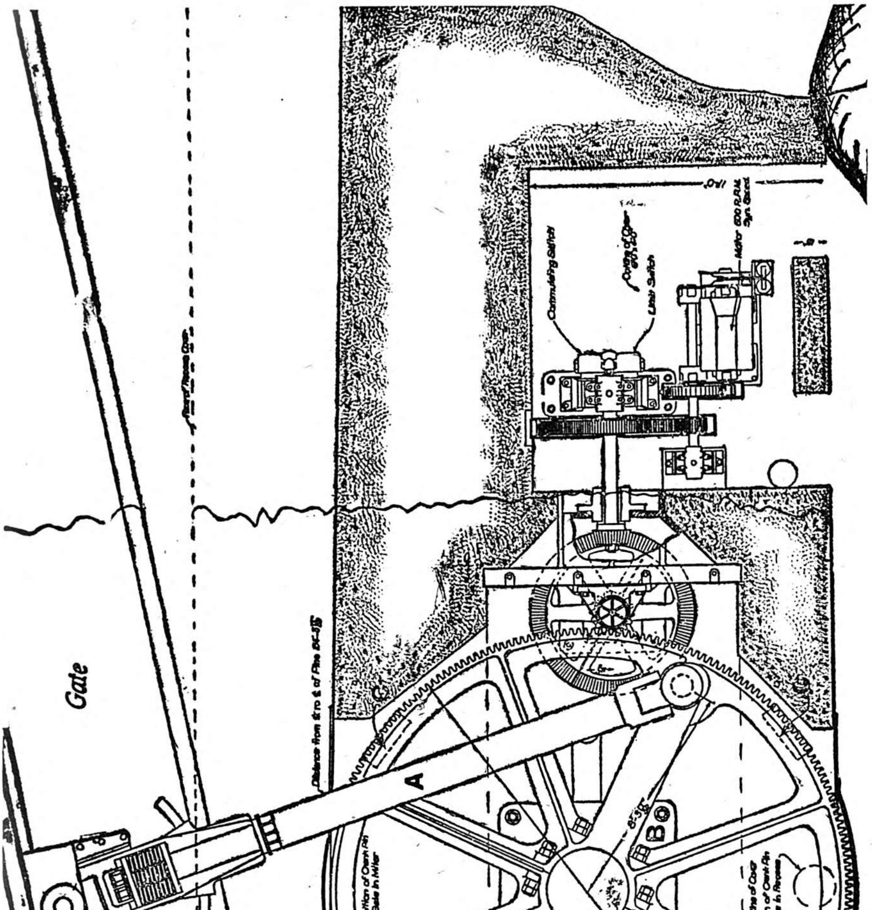
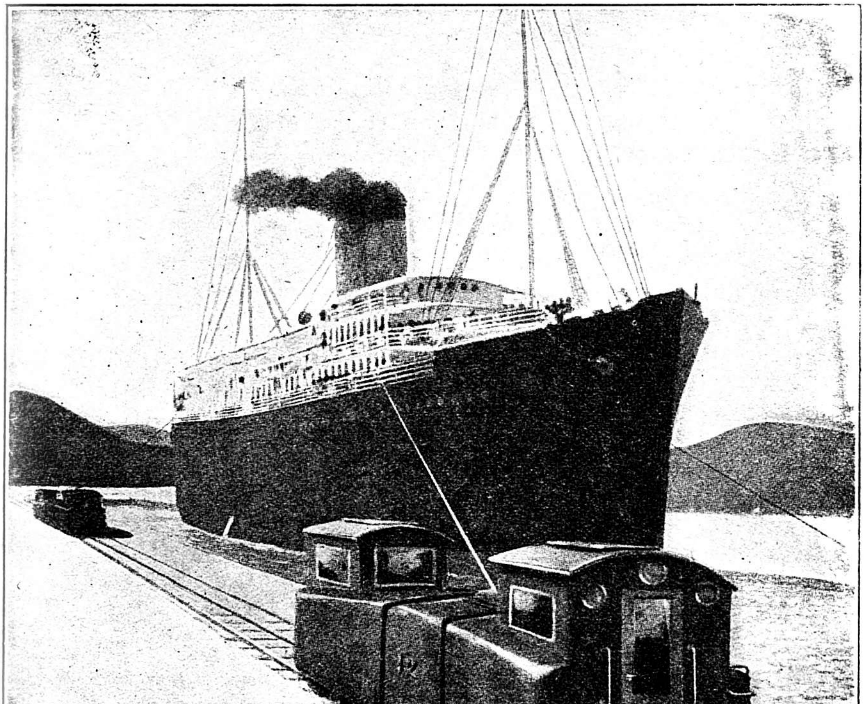


PLATE G—LOCK GATE OPERATING MACHINE SHOWING RELATION OF BULL WHEEL TO STRUT AND GATE

(A) Strut or Connecting Rod. (B) Bed Plate (C) Bearing Wheel.

Ships are not allowed to pass through the locks under their own power, but are towed through by electric locomotives operating on tracks on the lock walls. The system of towing provides for the passing through the locks of a ship at the rate of 2 miles an hour. The number of locomotives varies with the size of the vessel. The usual number required is 4: 2 ahead, 1 on each wall, imparting motion to the vessel, and 2 astern, 1 on each wall, to aid in keeping the vessel in a central position and to bring it to rest when entirely within the lock chamber. (Plate H.) They are equipped with a slip drum, towing windlass, and hawser which permit the towing line to be taken in or paid out without actual motion of the locomotive on the track. The locomotives run on a level, except when in passing from one lock to another they climb heavy grades. There are two systems of tracks, one for towing and the other for the return of the locomotives when not towing. The towing tracks have center racks or cogs throughout, and the locomotives always operate on this rack when towing. At the incline between locks the return tracks also have rack rails, but elsewhere the locomotives run by friction. The only crossovers between the towing and return tracks are at each end of the locks, and there are no switches in the rack rail.



Courtesy of "Popular Mechanics"

PLATE H---TOWING LOCOMOTIVES

NOTE.—The model of towing locomotive finally adopted is not in three sections, as appears in this illustration, but in one solid body on a single truck.

Several protective devices have been adopted to safeguard the gates in the locks.

First.—Fender chains, 24 in number, each weighing 24,098 pounds, are placed on the upstream side of the guard gates, intermediate and safety gates of the upper locks, and in front of the guard gates at the lower end of each flight of locks. They prevent the lock gates from being rammed by a ship that may approach the gates under its own steam or by escaping from the towing locomotives. In operation, the chain is stretched across the lock chamber from the top of the opposing walls, and when it is desired to allow a ship to pass, the chain is lowered into a groove made for the purpose in the lock floor. It is raised again after the ship passes. The raising and lowering are accomplished from both sides by mechanism mounted in chambers or pits in the lock walls. This mechanism consists of a hydraulically operated system of cylinders, so that 1 foot of movement by the cylinder will accomplish 4 feet by the chain. If a ship exerting a pressure of more than 750 pounds to the square inch should run into the fender, the chain will be paid out gradually by an automatic release until the vessel comes to a stop. Thus, a 10,000-ton ship, running at 4 knots an hour, after striking the fender can be brought to a stop within 73 feet, which is less than the distance which will separate the chain from the gate.

Second.—Double gates are provided at the entrances to all the locks and at the lower end of the upper lock in each flight, the guard gate of each pair protecting the lower gate from ramming by a ship which might possibly get away from the towing locomotives and break through the fender chain.

Third.—A dam of the movable type called an emergency dam (Plate I) is placed in the head bay above the upper locks of each flight for the purpose of checking the flow of water through the locks in case of damage, or in case it should be necessary to make repairs, or to do any work in the locks which would necessitate the shutting off of all water from the lake levels. Each dam is constructed on a steel truss bridge of the cantilever type, pivoted on the side wall of the lock approach, and when not in use resting on the side wall parallel to the channel. When the dam is used the bridge is swung across the channel with its end resting on the center wall of the lock. A series of wicket girders hinged to this bridge are then lowered into the channel with their ends resting in iron pockets embedded in the lock floor. After the girders have been lowered into place, they afford runways for gates which can be let down one at a time closing the spaces between the wicket girders. These gates form a horizontal tier spanning the width of the Canal and damming the water to a height of 10 feet. Another series of panels are then lowered, and so on until the dam, constructed from the bottom upward, completely closes the channel. When the dam has checked the main flow, the remainder, due to the clearance between the vertical sides of the gates, may be checked by driving steel pipes between the sides of the adjacent panels. These dams are operated in three movements, and the machinery for operating is, therefore, in three classes, gate-moving, raising and lowering the wicket girders, and hoisting the gates on the girders, all driven by electric motors.

Emergency Dam is shown closed with Wicket Girders and some Gates lowered in place.

Emergency Dam is shown open with Wicket Girders and Gates raised.

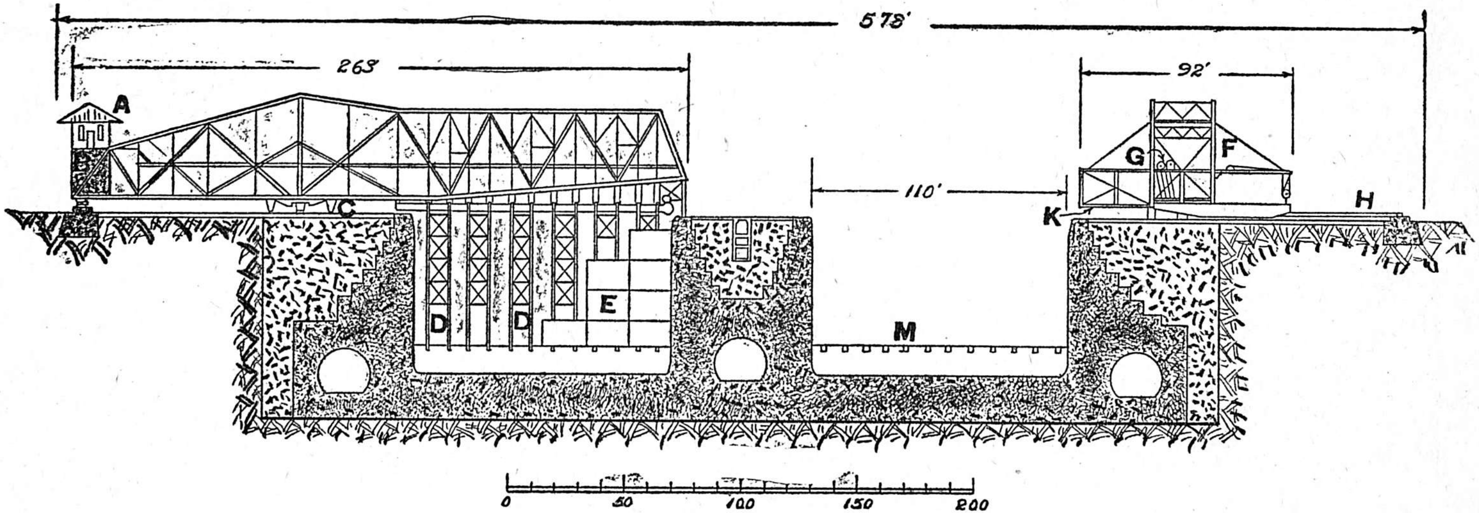


PLATE I—EMERGENCY DAMS AT MIRAFLORES LOCKS

A—Operator's House
B—Concrete Counterweight
C—Center Bearing
D—Wicket Girders
E—Gates
F—Girder-Hoisting Machinery
G—Gate-Hoisting Machinery
H—Quadrant
K—Horizontal Trus
M—Sill

To permit examining, cleaning, painting, and repairing the lower guard gates of the locks, and the Stoney gates of the Spillway dam, and for access in the dry to the sills of the emergency dams, floating caisson gates of the molded ship type are provided. When their use is required the caissons will be towed into position in the forebay of the upper lock, above the emergency dam, or between the piers of the Spillway, and sunk. The caissons are equipped with electric motor-driven pumps for use in pumping out the caissons and for unwatering the locks.

The gates, valves, and fender chains of the locks are operated by electricity, and remotely controlled from a central point; there is a central control station for each of the series of locks at Gatun, Pedro Miguel, and Miraflores. In passing a ship through the locks it is necessary to open and close the miter gates weighing from 390 to 730 tons, to fill and empty lock chambers containing from three and one-half to five million cubic feet of water, to raise and lower fender chains weighing 24,098 pounds each, and to tow the vessels through the locks. All these operations, except that of towing, are controlled by one man at a switchboard.

The control system for Gatun Locks is typical. Water is let into the lock chambers or withdrawn from them by means of culverts under the lock floors, which connect with larger culverts in the lock walls, through which water is carried from the higher to the lower levels. The main supply culverts are 18 feet in diameter, and the flow of water through them is controlled by rising-stem gate valves, which can be completely opened or closed in one minute. In the center wall the culvert feeds both lock chambers, and at each outlet into the lateral culverts there is a valve of the cylindrical type, in order that water may be let into or withdrawn from either chamber at will. A complete opening or closing of these cylindrical valves takes ten seconds. The miter gates are never opened or closed with a head of water on either side of them, the chambers being first emptied or filled by means of the valve and culvert system. The time required either to open or close the miter gate is two minutes.

A ship to be raised to the lake level will come to a full stop in the forebay of the lower lock, prepared to be towed through one of the duplicate locks by electric towing locomotives. The water in the lower lock chamber will be equalized with the sealevel channel, after which the miter gates will be opened, the fender chain lowered and the vessel passed into the first chamber, where the water is at sealevel. Then the miter gates will be closed. The rising stem gate valves at the outlet of the main culverts will be closed, while those above will be opened, allowing water to flow from an upper level into the lower chamber, which, when filled, will raise the vessel $28\frac{1}{3}$ feet, to the second level. This operation will be repeated in the middle and upper locks until the ship has been raised to the full height of 85 feet above the level of the sea. At Gatun, in the passing of a large ship through the locks, it will be necessary to lower 4 fender chains, operate 6 pairs of miter gates and force them to miter, open and close 8 pairs of rising stem gate valves for the main supply culverts, and 30 cylindrical valves. In all, no less than 98 motors will be set in motion twice during each lockage of a single ship, and this number may be increased to 143, dependent upon the previous conditions of the gates, valves, and other devices.

Each gate leaf, valve, and fender chain is operated by a separate motor mounted near the machinery in chambers in the lock wall, the motors acting through suitable gears (or pump in the fender chain) upon the various machines. In each machinery chamber there is a starting panel containing contactors by which current is applied to the motor and these panels in turn are controlled from a main unit in the central control house. Some of the machinery chambers at Gatun are 2,700 feet distant from the point of control. Ninety per cent of them are within 2,000 feet, and 50 per cent of the total within 1,200 feet.

The station from which control is exercised over the movement of all the machines is on the center wall at the lower end of the upper flight of locks at Gatun, and similarly placed at Pedro Miguel and Miraflores. It is in a building raised high enough above the top of the wall to allow a towing locomotive to pass under, a height of 16 feet, and to command an uninterrupted view of every part of the locks. In this house is a double-control board duplicated to conform to the duplication in locks. The control board is in the nature of a bench or table, 32 inches above the floor, containing a representation, part model and part diagrammatic, of the flight of locks controlled by the respective series of switches. Standing at his switchboard the operator throws the switches, and sees before him in model or diagram the progress of the fender chains as they rise and fall, the movement of the miter gates inch by inch, the opening and closing of the gate valves in the main culverts at every stage, the operation of the cylindrical valves, and, in addition, indication of the gradual rise or fall of the water in the lock chambers. The switches controlling the various motors, together with their indicators, are mounted upon the board in the same relative position as the machines themselves in the lock walls. Some distortion of scale is allowed to give room for the switches. The board must not be over 4 feet in width, in order that the operator may be able to reach beyond the middle of it, and the length of the board is limited to 64 feet at Gatun, and proportionally at the other locks.

The system is interlocking, so that certain motors cannot be started in a certain direction until other motors are operated in a proper manner to obtain consistent operation on the whole, and to avoid any undesirable or dangerous combinations in the positions of valves, gates, or fender chains. In this way and by the use of limit switches the factor of the personal equation in operating the machines is reduced to a minimum, almost mechanical accuracy being obtained. Before the operating pair of valves in the main culverts can be opened, at least one pair of valves at the other ends of the locks, both upstream and downstream, must first be closed. This limits an operator to the act of equalizing water levels between locks, and keeps him from allowing water to flow from, say, the lake level to the middle lock past the upper lock, thus preventing a possible flooding of the lock walls and machinery rooms. Interlocks, devoted to the control of action between the gate valves in the main culverts and the miter gates, prevent valves being opened a lock length above or below a miter gate which is being opened or closed, and thus prevent an operator causing a flow of water while the miter gates are being moved. Interlocks for the cylindrical valves guarding the openings from the center wall culvert to the lateral culverts keep those of one side or the other closed at all times, except when it may be desired to cross-fill the chambers, when they may be opened by special procedure. An interlock prevents the operator from starting to open a miter gate before unlocking the miter-forcing machine. The miter gates guarded by a fender chain must be opened before the chain can be lowered, and the chain must be raised again before the gate can be closed, or more exactly the switches must be thrown in this order, but the operations may proceed at the same time. The simple interlocks will prevent such a mistake as leaving the chain down through lapse of memory, when it should be up to protect the gate.

The general scheme of lighting and buoying the Canal includes the use of range lights to establish direction on the longer tangents and of side lights spaced about 1 mile apart to mark each side of the channel. The range lights are omitted in Culebra Cut, where their use is hardly practicable, and on four of the shorter tangents on the remainder of the Canal. In the Cut there are three beacons at each angle, and between these intermediate beacons in pairs on each side of the Canal. By keeping his ship pointed midway between these beacons, the pilot is able to adhere closely to the center of the Canal. At each tangent it is necessary to have two ranges of two lights each to prolong the sailing line in order that the pilot may hold his course up to the point of turning. These range lights are situated on land. There are three types constructed, as shown by the cuts herewith, all of reinforced concrete (Plate J). The more elaborate structures are used on the Gatun locks and dam and in the Atlantic and Pacific Divisions, where they are closer to the sailing lines of the vessels, while simpler structures are placed in the Gatun Lake, where they are under less close observation. A light and fog signal on the west breakwater in Limon Bay is also included (Plate K), and a light on the east breakwater. The illuminants are gas and electricity, the latter being used whenever the light is sufficiently accessible. For the floating buoys, and for the towers and beacons which are in inaccessible places, the system using compressed acetylene dissolved in acetone has been adopted. The buoys are composed of a cylindrical floating body or tank, surmounted by a steel frame which supports the lens at a height of about 15 feet above the water level. The buoys are moored in position along the edge of the dredged channel by a heavy chain and a concrete sinker, and should remain lighted for six to twelve months without being recharged. The candlepower of the range lights varies according to the length of the range, from about 2,500 to 15,000 candlepower. The most powerful lights are those marking the sea channels at the Atlantic and Pacific entrances, they being visible from about 12 to 18 nautical miles. The beacons and gas-buoy lights have about 850 candle-

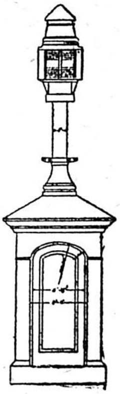


FIG. 3---BEACON FOR CULEBRA CUT

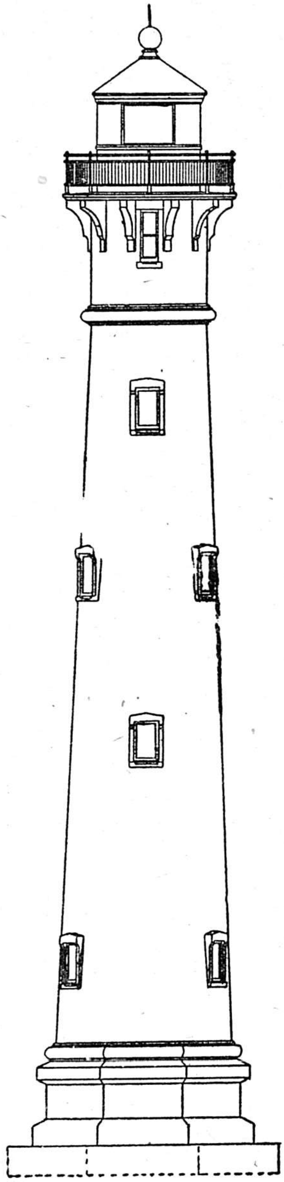


FIG. 1---ATLANTIC AND PACIFIC SECTIONS

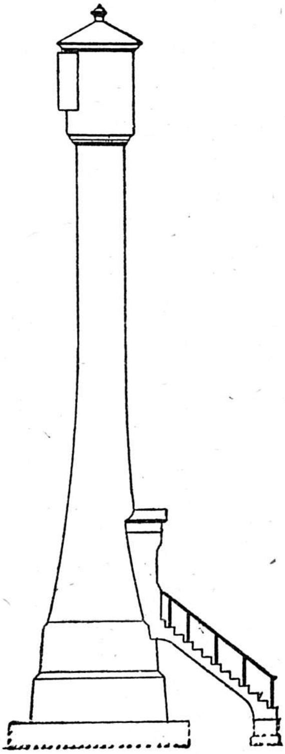


FIG. 2---GATUN LAKE

PLATE J—RANGE LIGHT TOWERS AND BEACONS

power. White lights are used throughout, and, in order to eliminate the possibility of confusing the lights with one another and with the lights on shore, all range lights, beacons, and buoys have individual characteristics formed by flashes and combinations of flashes of light and dark intervals.

The total excavation, dry and wet, for the Canal as originally planned, was estimated at 103,795,000 cubic yards, in addition to the excavation by the French companies. Changes in the plan of the Canal, made subsequently by order of the President, increased the amount to 174,666,594 cubic yards. Of this amount, 89,794,493 cubic yards were to be taken from the Central Division, which includes the Culebra Cut. In July, 1910, a further increase of 7,871,172 cubic yards was made, of which 7,330,525 cubic yards were to allow for slides in Culebra Cut, for silting in the Chagres section, and for lowering the bottom of the Canal from 40 to 39 feet above sealevel in the Chagres section. These additions increased the estimated total excavation to 182,537,766 cubic yards. In 1911, a further increase of 12,785,613 cubic yards was made, of which 5,257,281 cubic yards was for slides in Culebra Cut, and the remainder for additional excavation and silting in the Atlantic and Pacific entrances, raising the grand total of estimated excavation to 195,323,379 cubic yards. In 1912, a still further increase was made of which 3,545,000 cubic yards was for slides in Culebra Cut, and the remainder for dredging excavation at Gatun locks, silting in the Atlantic entrance, and for the Balboa terminals, bringing the grand total of estimated excavation to 212,227,000 cubic yards. In July, 1913, a final revised estimate placed the total at 232,353,000 cubic yards, an increase over that of 1912 of 20,126,000 cubic yards, of which 9,067,000 was for slides and breaks in Culebra Cut.

The points of deepest excavation are in Culebra Cut, 495 feet above the bottom of the Canal at Gold Hill, and 364 feet above at Contractor's Hill, opposite. The widest part of the Cut is opposite the town of Culebra, where owing to the action of slides on both banks, the top width is about half a mile. (Plate L.) Active excavation work on a large scale did not begin until 1907, when 15,765,290 cubic yards were removed. In 1908, over 37,000,000 cubic yards were removed, and in 1909, over 35,000,000 making a total for the two years of over 72,000,000 yards, or a monthly average for those two years of 3,000,000 cubic yards. In the succeeding three years the monthly average exceeded 2,500,000 cubic yards. Records of all excavation to October 1, 1913, are appended. Excavation by steamshovels in Culebra Cut ceased on September 10, 1913. In all there was excavated from the Cut by steamshovels, 97,191,000 cubic yards. On October 5, the admission of water from Gatun Lake was begun through pipes in the dike at Gamboa. On October 10, the dike was blown up by dynamite, and the water of the lake was let in bringing the level in the Cut to that of the lake.

By French Companies		78,146,960
French excavation useful to present Canal		29,908,000
By Americans:		
Dry excavation	127,816,068	
Dredges	83,232,130	
Total		211,048,198
May 4 to December 31, 1904	243,472	
January 1 to December 31, 1905	1,799,227	
January 1 to December 31, 1906	4,948,497	
January 1 to December 31, 1907	15,765,290	
January 1 to December 31, 1908	37,116,735	
January 1 to December 31, 1909	35,096,166	
January 1 to December 31, 1910	31,437,677	
January 1 to December 31, 1911	31,603,899	
January 1 to December 31, 1912	30,269,349	
January 1 to October 1, 1913	22,767,886	

TOTALS BY DIVISIONS AND AMOUNT REMAINING TO BE EXCAVATED.

Divisions.	Amount excavated.	Remaining to be excavated.
Atlantic—		
Dry excavation	8,849,590	5,410
Dredges	39,106,048	5,205,952
Total	47,955,638	5,211,362
Central—		
Culebra Cut	97,191,000	7,821,000
All other points	12,384,655	300,345
Total	109,575,655	8,121,345
Pacific—		
Dry excavation	9,982,836	805,164
Dredges	43,534,069	7,166,931
Total	53,516,905	7,972,095
Grand total	211,048,198	21,304,802

There have been in all 31 slides and breaks in Culebra Cut; 17 covered areas varying from 1 to 75 acres, and 14 covered areas of less than 1 acre each, making in all a total of 251 acres. One variety of slide was caused by the slipping of the top layer of clay and earth on a smooth sloping surface of a harder material. The largest slide of this character was that known as Cucaracha on the east bank of the Canal just south of Gold Hill. This gave the first French company trouble during the final years of its operations. It first gave the Americans trouble in 1905, and between that date and July 1, 1912, nearly 3,000,000 cubic yards of material were removed from the Canal because of it. It broke nearly 1,900 feet back from the axis of the Canal and covered an area of 47 acres. Another variety of slide, properly called break, was due to the steepness of the slopes and the great pressure of the superincumbent material upon the underlying layers of softer material. The largest slide or break of this type was on the west side of the Cut at Culebra just north of Contractor's Hill and covered an area of 75 acres. Over 7,000,000 cubic yards of material have been removed from this slide and it is thought that by the time the Canal shall have been completed something like 10,000,000 cubic yards will have been taken out. On the east side of the Cut a similar slide covers an area of about 50 acres, breaking back about 1,300 feet from the center of the Canal. About a half million cubic yards have been taken out of this slide and more remains to be removed. It is estimated that the total amount of material removed from the Canal because of the slides will aggregate between 24,000,000 and 25,000,000 cubic yards.

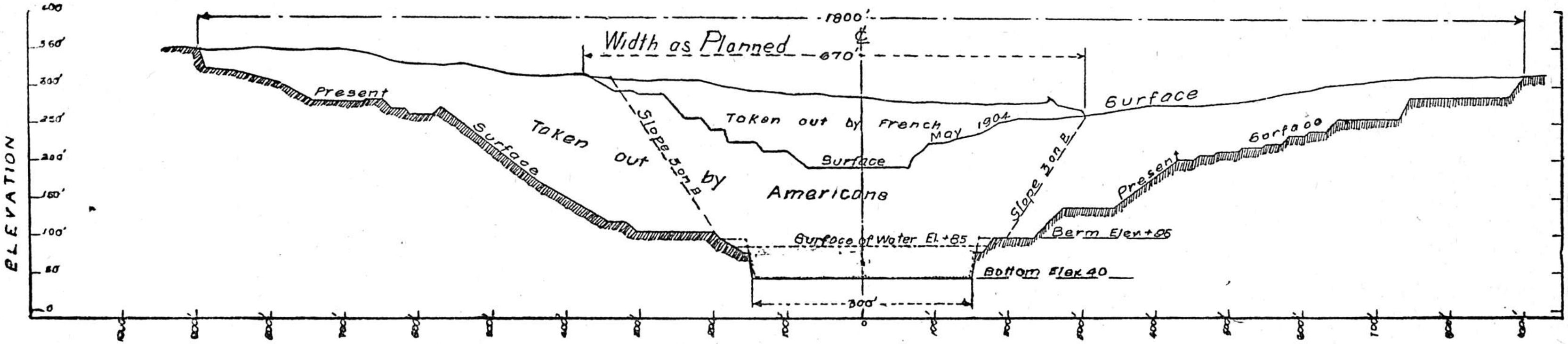


PLATE L—CROSS SECTION OF CULEBRA CUT SHOWING LARGEST EFFECT OF SLIDES

Most of the material excavated in Culebra Cut consisted of rock varying from very soft, which readily disintegrates on exposure to the atmosphere, to very dense rock of great hardness. It was necessary before excavating this material to drill and blast it. Two kinds of drills were used—tripod and well—both obtaining their power from a 10-inch compressed air main on the west bank of the Cut which was supplied by three batteries of air compressors placed at equal distances along the 9 miles of the Cut. The usual depth of drill holes was about 27 feet, three feet deeper than the steamshovels were excavating. The drill holes, placed about 14 feet apart, were loaded with 45 per cent potassium nitrate dynamite in quantities depending upon the character of the rock, and were connected in parallel and fired by means of a current from an electric light plant. The maximum number of drills in use at any one time in Culebra Cut was 377 of which 221 were tripod and 156 well. With these over 90 miles of holes were drilled in a single month. A pound of dynamite was used to about every 2 cubic yards of material blasted, and the quantity used in Culebra Cut during several years averaged about 6,000,000 pounds a year.

There were several classes of steamshovels engaged in excavating work, equipped with dippers ranging in capacity from 1¾ cubic yards to 5 cubic yards, and a trenching shovel, with a dipper having a capacity of ¾ of a cubic yard. In Culebra Cut excavation the 5-yard dippers were used almost entirely.

Each cubic yard, place measurement, of average rock weighs about 3,900 pounds; of earth, about 3,000 pounds; of "The run of the Cut" about 3,600 pounds, and is said to represent about a two-horse cart load. Consequently, a 5-cubic yard dipper, when full, carries 8.7 tons of rock, 6.7 tons of earth, and 8.03 tons of "The run of the Cut."

Three classes of cars were used in hauling spoil—flat cars with one high side, which are unloaded by plows weighing from 14 to 16 tons, operated by a cable upon a winding drum, and two kinds of dump cars, one large and one small. The capacity of the flat cars was 19 cubic yards; that of the large dump cars, 17 cubic yards, and that of the small dump cars, 10 cubic yards. The flat-car train was ordinarily composed of 20 cars in hauling from the Cut at Pedro Miguel, and 21 cars in hauling from the Cut at Matachin. The large dump train was composed of 27 cars, and the small dump train of 35 cars.

The average load of a train of flat cars, in hauling the mixed material known as "The run of the Cut," was 610.7 tons (based on a 20-car train); of a train of large dump cars, 737.68 tons, and of a train of small dumps, 562.5 tons.

The average time consumed in unloading a train of flat cars was from 7 to 15 minutes; in unloading a train of large dump cars, 15 to 40 minutes; and in unloading a train of small dump cars, 6 to 56 minutes. The large dump cars were operated by compressed air power furnished by the air pump of the locomotive, while the small dump cars were operated by hand.

The record day's work for one steamshovel was that of March 22, 1910—4,823 cubic yards of rock (place measurement), or 8,395 tons. The highest daily record in the Central Division was on March 11, 1911, when 51 steamshovels and 2 cranes, equipped with orange peel buckets, excavated an aggregate of 79,484 cubic yards, or 127,742 tons. During this day, 333 loaded trains, and as many empty trains, were run to and from the dumping grounds.

The greatest number of shovels in use at one time in the Cut was 43, and the greatest monthly excavation in any single month, in the Cut, was obtained in March, 1911, when 1,728,748 cubic yards of material, mostly rock, were excavated.

To handle this amount of material required the services of 115 locomotives and 2,000 cars, giving about 160 loaded trains per day to the dumps, which on the average were about 12 miles distant, the haul one way varying from about one mile to 33 miles. To serve properly the trains and shovels employed in excavation work in the Cut, although it is less than nine miles in length, about 100 miles of track were required, or an average of over nine parallel tracks at all parts.

Breakwaters have been constructed at the Atlantic and Pacific entrances of the Canal. That in Limon Bay or Colon Harbor, extends into the bay from Toro Point at an angle of 42° and 53′ northward from a base line drawn from Toro Point to Colon light, and is 10,500 feet in length, or 11,700 feet, including the shore connection, with a width at the bottom of fifteen feet and a height above mean sea-level of ten feet. The width at the bottom depends largely on the depth of water. It contains approximately 2,840,000 cubic yards of rock, the core being formed of rock quarried on the mainland near Toro Point, armored with hard rock from Porto Bello. Work began on the breakwater in August, 1910, and on December 1, 1912, the trestle and fill were completed to full length, 11,500 feet. The estimated cost is $5,500,000. A second breakwater has been authorized for Limon Bay, known as the east breakwater. It will be without land connection and about one mile long. The purpose of the breakwaters is to convert Limon Bay into a safe anchorage, to protect shipping in the harbor of Colon, and vessels making the north entrance to the Canal, from the violent northers that are likely to prevail from October to January, and to reduce to a minimum the amount of silt that may be washed into the dredged channel.

The breakwater at the Pacific entrance extends from Balboa to Naos Island, a distance of about 17,000 feet, or a little more than three miles. It lies from 900 to 2,700 feet east of and for the greater part of the distance nearly parallel to the axis of the Canal prism; varies from 20 to 40 feet in height above mean sealevel, and is from 50 to 3,000 feet wide at the top. It contains about 18,000,000 cubic yards of earth and rock, all of which was brought from Culebra Cut. It was constructed for a twofold purpose; first, to divert cross-currents that would carry soft material from the shallow harbor of Panama into the Canal channel; second, to furnish rail connection between the islands and the mainland. Work was begun on it in May, 1908, and on November 6, 1912, the last piles were driven connecting Naos Island with the mainland.

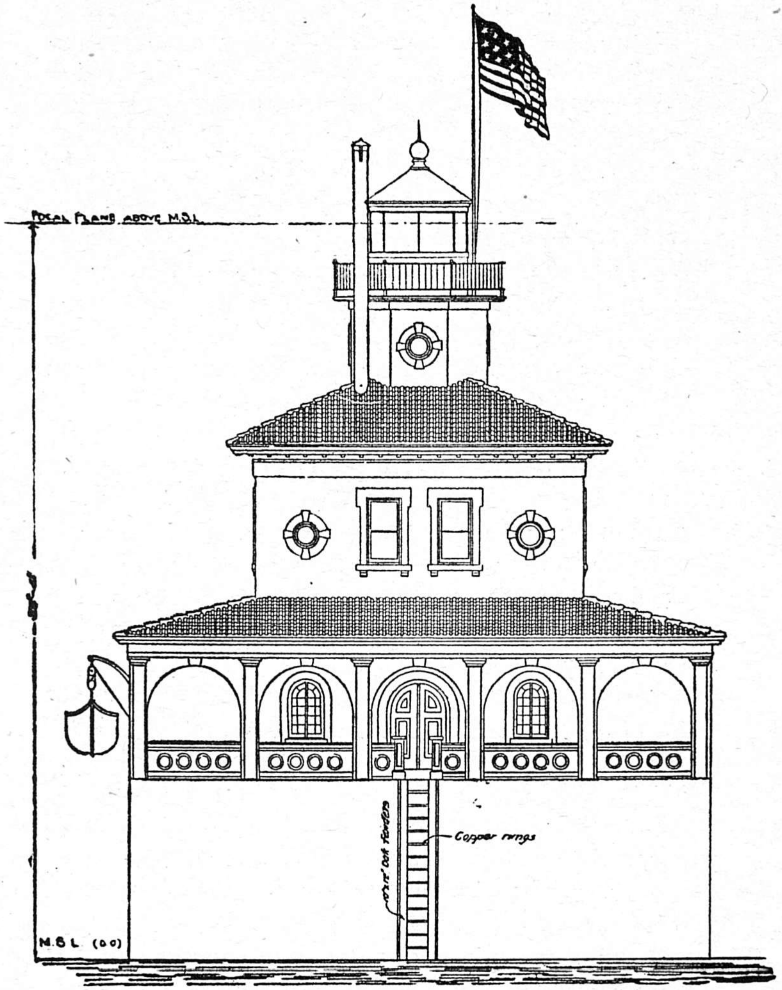


PLATE K—WEST BREAKWATER LIGHTHOUSE—56′ 4″ HIGH

Payment to the New Panama Canal Company	$40,000,000.00
Payment to Republic of Panama	10,000,000.00
Appropriation, June 28, 1902	10,000,000.00
Appropriation, December 21, 1905	11,000,000.00
Deficiency, February 27, 1906	5,990,786.00
Appropriation, June 30, 1906	25,456,415.08
Appropriation, March 4, 1907	27,161,367.50
Deficiency, February 15, 1908	12,178,900.00
Appropriation, May 27, 1908	29,187,000.00
Deficiency, March 4, 1909	5,458,000.00
Appropriation, March 4, 1909	33,638,000.00
Deficiency, February 25, 1910	76,000.00
Appropriation, June 25, 1910	37,855,000.00
Appropriation, March 4, 1911	45,560,000.00
Appropriation, August 24, 1912	28,980,000.00
Appropriation, June 23, 1913	16,265,393.00
Private Act. Relief of Elizabeth G. Martin	1,200.00
Private Act. Relief of Marcellus Troxell	1,500.00
Private Act. Relief of W. L. Miles	1,704.18
Private Act. Relief of Chas. A. Caswell	1,056.00
Private Act. Relief of Alexandro Comba	500.00
Private Act. Relief of Douglas B. Thompson	1,500.00
Private Act. Relief of Robert S. Gill	2,520.00
Private Act. Relief of Peter Wigginton	500.00
Private Act. Relief of Raymond R. Ridenour	500.00
Private Act. Relief of heirs of Charles E. Stump	1,500.00
Private Act. Relief of parents of Edward Maher	1,980.00
Private Act. Relief of Oscar F. Lackey	1,500.00
Private Act. Relief of Pedro Sanchez	2,000.00
Private Act. Relief of John H. Cole	1,951.38
Private Act. Relief of Robert Coggan	1,500.00
Judgment, Court of Claims, Timothy J. Butler	196.45
Total	338,828,469.59
Appropriation for Fortifications, March 4, 1911	3,000,000.00
Appropriation for Fortifications, August 24, 1912	2,806,950.00
Appropriation for Fortifications, June 23, 1913	4,870,000.00
Grand total	349,505,419 59

CLASSIFIED EXPENDITURES TO JULY 31, 1913.

Department of Construction and Engineering	$185,826,891.83
Department of C. and E., Plant	1,627,744.31
Department of Sanitation	16,371,652.40
Department of Civil Administration	6,454,781.54
Department of Law	46,580.18
Panama Railroad, Second Main Track	1,152,026.47
Panama Railroad, Relocated Line	8,983,863.70
Purchase and Repair of Steamers	2,680,112.01
Zone Waterworks and Sewers	5,636,884.33
Zone Roadways	1,631,099.55

Loans to Panama Railroad Company	$3,247,332.11
Construction and Repair of Buildings	10,298,612.40
Purchase from New Panama Canal Company	40,000,000.00
Payment to Republic of Panama	10,000,000.00
Miscellaneous	4,474,507.26
Total	298,432,088.09
Expenditures for Fortifications to July 31, 1913	3,245,691.23

The balances carried in expenditure accounts, which are included in the last item above, for waterworks, sewers, and pavements in the cities of Panama and Colon amounted altogether to $2,400,738.36. The unexpended balance in the appropriation for sanitation in the cities of Panama and Colon, available for expenditures on waterworks, sewers, and pavements was $85,980.15, including transfer of appropriations for the quarter ending June 30, 1913.

A careful official estimate has been made by the Canal Commission of the value to the Commission at the present time of the franchises, equipment, material, work done, and property of various kinds for which the United States paid the French Canal Company $40,000,000. It places the total value at about $43,000,000, divided, as follows:

Excavation, useful to the Canal, 29,708,000 cubic yards	$25,389,240.00
Panama Railroad Stock	9,644,320.00
Plant and material, used, and sold for scrap	2,112,063.00
Buildings used	2,054,203.00
Surveys, plans, maps, and records	2,000,000.00
Land	1,000,000.00
Clearings, roads, etc	100,000.00
Ship channel in Panama Bay, four years' use	500,000.00
Total	42,799,826 00

Of the 436 square miles of Zone territory the greater part is owned by the United States and the Panama Railroad Company, the balance being owned by private individuals and corporations.

All of the privately owned lands in the Canal Zone are being taken over on behalf of the United States by virtue of the Executive Order of the President of December 5, 1912, acting by authority of the Panama Canal Act of August 24, 1912.

Under the Treaty with Panama the United States acquired a strip extending for five miles on either side of the Canal, and all other lands and land under water needed for Canal purposes. The Treaty vests the title in the United States to public lands in the Canal Zone, and a title in the nature of an option on privately owned lands, upon condition that the United States will compensate the owners of the lands in the event that the option is exercised by the United States. Consequently, the owners of the private lands in the Canal Zone, now being taken over by the United States under the Executive Order of the President, will be compensated in damages, to be fixed either by private agreement, or by the Joint Land Commission.

The United States has jurisdiction and ownership over the area to be covered by Gatun Lake, which extends beyond the line of the Canal Zone. Gatun Lake will have a summit level of 87 feet, and the Government of the United States has taken an additional strip around the lake littoral up to the 100-foot level, the additional strip being needed for police and sanitary purposes. The area of this territory is 24,427 hectares, or appioximately 95½ square miles.

The Canal force is recruited and housed by the Quartermaster's Department which has two general branches, labor and quarters, and material and supplies. Through the labor and quarters branch there have been brought to the Isthmus 45,107 laborers, of whom 11,873 came from Europe, 19,900 from Barbados, the balance from other islands in the West Indies, and from Colombia. No recruiting is required at present, the supply of labor on the Isthmus being ample.

On September 24, 1913, the total force of the Isthmian Canal Commission and Panama Railroad Company, actually at work, was divided, as follows:

	Gold	Silver	Total
Isthmian Canal Commission	3,786	28,480	32,266
Panama Railroad Company	476	3,334	3,810
Panama Railroad Commissary	262	1,162	1,424
Total	4,524	32,976	37,500

In addition to the above, there were in the employ of contractors on the Isthmus, 433 gold and 1,849 silver employes, a total of 2,282.

The gold force is made up of the officials, clerical force, construction men, and skilled artisans of the Isthmian Canal Commission and Panama Railroad Company. Practically all of them are Americans. The silver force represents the unskilled laborers of the Commission and the Panama Railroad Company. Of these, about 4,000 are Europeans, mainly Spaniards, with a few Italians and men of other races. The remainder, about 28,000, are West Indians, about 6,500 of whom are employed as artisans receiving 16, 20, 25, 32, and 44 cents an hour, and 5,500 on a monthly basis. The standard rate for the West Indian laborer is 10 cents an hour, but a few of these doing work of an exceptional character are paid 16 and 20 cents. The larger part of the Spaniards are paid 20 cents an hour, and the rest 16 cents an hour.

The material and supply branch carries, in six general storehouses, a stock of supplies for the Commission and Panama railroad valued approximately at $3,437,000 (July 1, 1913). About $13,980,000 (1912–1913) worth of supplies are purchased annually, requiring the discharge of one steamer each day.

The Canal and Panama railroad forces are supplied with food, clothing, and other necessaries through the Subsistence Department, which is divided into two branches—Commissary and Hotel. It does a business of about $9,100,000 per annum. The business done by the Commissary Department amounts to about $7,600,000 per annum, and that done by the hotel branch to about $1,500,000 per annum.

The Commissary system consists of 20 general stores in as many Canal Zone villages and camps along the line of the Panama railroad. It is estimated that with employes and their dependents, there are about 65,000 people supplied daily with food, clothing, and other necessaries. In addition to the retail stores, the following plants are operated at Cristobal: Cold storage, ice making, bakery, coffee roasting, ice cream, laundry, industrial laboratory, and packing department.

A supply train of 21 cars leaves Cristobal every morning at 3 o'clock. It is composed of refrigerator cars containing ice, meats, and other perishable articles, and 10 cars containing other supplies. These are delivered at the stations along the line and distributed to the houses of employes by the Quartermaster's Department.

The hotel branch maintains the Hotel Tivoli, at Ancon, and also 14 hotels along the line for white gold employes at which meals are served for 30 cents each. At these 14 hotels there are served monthly about 200,000 meals. There are 13 messes for laborers serving 40-cent rations to Europeans and 27-cent rations to West Indians. The rations include three meals. There are served at these messes about 235,000 meals per month of the European ration and 115,000 meals per month of the West Indian ration. The supplies for one month for the line hotels and messes cost about $85,000; labor and other expenses amount to about $17,000. The monthly receipts, exclusive of the revenue from the Hotel Tivoli, amount to about $105,000.

HEADQUARTERS AND OTHER BUILDINGS.

The permanent administration and Canal headquarters building is in process of erection on a knoll northwest of Ancon quarry where it will overlook both the terminal piers and the Canal entrance. It is to have 75,000 square feet of floor space and is to cost $375,000, including $25,000 for that part assigned to permanent records. The quarters for gold employes attached to the administration building will be erected in the general area adjacent to and northeast of it, and gold employes connected with the shops, docks, and other terminal facilities at Balboa will be housed in quarters erected in the area surrounding the eastern slope of Sosa Hill, and on the fill between Ancon and Sosa hills, adjoining the Ancon-Balboa highway. Silver employees will be quartered in a settlement, to be known as La Boca, that has been laid out along the edge of Balboa dump, south of Sosa Hill. There will be a permanent settlement at Pedro Miguel for employes of the Pacific locks, and one at Gatun for employes of the Atlantic locks. The settlements at Cristobal and Ancon will continue to be maintained. Dredging headquarters have been established at Paraiso. No necessity is apparent for any other than the foregoing permanent settlements, except for the military forces which may be stationed on the Isthmus.

PIERS.

The piers for commercial use at Balboa will be built at right angles to the axis of the Canal, with their ends about 2,650 feet from the center line of the Canal channel. They will be 1,000 feet long, and 201 feet wide, with 300-foot slips between, and with landings for small boats at the head of each slip 242 feet in length. The construction of one pier only is being undertaken at first. The old French steel wharf, about 1,000 feet long, will be retained as long as it may be required, for commercial purposes.

Two wharves and one pier are under construction by the Panama railroad at Cristobal, behind a mole or breakwater, built out from the shore toward the Canal channel, and paralleling the boundary line between Canal Zone and Panamanian waters. Primarily, these docks are to meet the present commercial requirements. Should additional docks be found necessary after the Canal is completed, four other piers, each 1,042 feet long and 209 feet wide, with 300-foot slips between, can be constructed behind the mole.

DRYDOCKS.

The main drydock will be situated at Balboa, and will be capable of accommodating any vessel that can pass through the Canal locks. It will have a usable length of 1,000 feet, a depth over the keel blocks of 35 feet at mean sealevel, and an entrance width of 110 feet. The entrance will be closed by miter gates, similar to those used in the locks. The drydock will be of concrete resting on hard rock. Its equipment will include a 50-ton locomotive crane, with a travel on both sides.

For vessels of smaller type, an auxiliary drydock will be built at Balboa, in lieu of the marine railways originally contemplated. It will have a usable length of 350 feet, a width at entrance of 71 feet, and a depth over the keel blocks at 16 feet at mean sealevel. It will be provided with a floating caisson. The 50-ton locomotive crane will serve for this dock also. Work on these drydocks, as well as for the new shops, is now under way. Preliminary work in preparing the site required the excavation of about 300,000 cubic yards of rock from the west face of Sosa Hill. The excavated material was used in filling the site for the shops and terminal yard.

On the Atlantic side it is proposed to retain the old French drydock at Mount Hope, which has a usable length of 300 feet, a width at entrance of 50 feet, and a depth over the sill of 13 feet at mean sea level. It was the opinion of the board on terminals, that the commercial requirements in sight would not warrant the construction of another drydock at Cristobal, at the expense of the Canal, capable of accommodating large vessels, in view of the drydock at Balboa, to which any large vessel on the Atlantic side could be taken and returned, in case it was found necessary.

SUPPLIES FOR SHIPS.

All vessels using the Canal will be offered the opportunity to purchase at Government rates supplies of all kinds, cold storage, fresh water, and fuel.

COALING PLANTS.

There will be large coaling plants at both ends of the Canal. In general, each plant will consist of two water fronts and a storage pile. The water fronts will be designated as the unloading wharf and the reloading wharf, while the storage pile is to consist of a basin for coal, a part of which is to be stored subaqueously, and the remainder in the dry. Each plant will be arranged to receive, store, and deliver separately, coal belonging to individuals and companies, as well as to the Government; to receive it from any part of the unloading wharf and transport it to any part of the storage pile; to reclaim coal from any part of the storage pile and deliver it to any part of the reloading wharf, and to transfer it from any part of the storage pile to any other part of same. Coal will be received by each plant by movable unloading towers running on rails supported by the unloading wharf, and reloaded to colliers and barges by movable reloaders running on rails supported by the reloading wharf. The storage pile at the Cristobal plant is to be commanded by movable stocking and reclaiming bridges running on rails.

This will be the main coaling plant, and the storage facilities, exclusive of the stock of individuals and companies, will be:

	Tons.
Wet storage, reserved for naval use	100,000
Dry storage, for Canal use	70,000
Emergency storage, dry	30,000
Total	200,000

The storage pile at Balboa will be commanded by four berm cranes, formerly used at the Pacific locks, traveling on rails supported by a suitable concrete and steel trestle running longitudinally of the basin.

This plant will be secondary in importance to the plant at Cristobal, and its storage capacity and facilities for handling will be about one-half of those of the main plant, as follows:

	Tons.
Wet storage, reserved for naval use	55,000
Dry storage, for Canal use	40,000
Emergency storage, dry	20,000
Total, not including storage for individuals and companies	115,000

FUEL OIL.

In addition to coal, fuel oil will be supplied at both ends of the Canal. Four steel tanks, each with a capacity of 42,000 barrels of oil, have been erected, two at Cristobal and two at Balboa. Each tank is 93 feet in diameter and 35 feet high. Land has been set aside also at both ends for the erection of oil tanks by individuals and companies, which will be leased on revocable licenses. The Government will install the necessary oil-pumping plants at the water fronts with oil mains running to the tanks.

SHOPS.

The main repair shops are under construction at Balboa, and are designed to maintain the following equipment:

1. Lock, spillway, and power plant machinery. 2. Water and land equipment retained for the maintenance of the Canal. 3. Rolling stock and equipment of the Panama railroad. 4. Mechanical apparatus connected with the coaling plants, fortifications, cold storage plant, wireless stations, etc. 5. The making of repairs, etc., required by commercial vessels, and by private individuals and corporations. 6. The making of such repairs as may be required by vessels of the United States Navy.

All of the buildings will be of permanent construction, with steel frames. The sides and ends will, in general, be protected from sun and rain by overhanging sheds and by movable metal louvres.

The main metal working shops, including machine, erecting, and tool shops, the forge and pipe shop, and the boiler and shipfitters' shop, together with the shed for the storage of steel, will be placed end on between the drydock and repair wharf. The general storehouse, foundry, woodworking shops, subsidiary buildings, and office building, will be erected parallel to the line of the drydock and water front, northeast of the main shops. Two lines of railroad tracks will extend past each end of the main metal working shops, and one track through their center. The main shops will be provided with overhead traveling cranes, the crane runways being extended through each end of the buildings over the railroad tracks. As far as possible, the present machinery is utilized in the new shops. All of it is electrically driven, including both individual and group drive.

It is proposed to retain the old Cristobal drydock shops for making repairs on the Atlantic side, until sufficient experience is had to determine the extent and character of repair facilities necessary.

FLOATING EQUIPMENT.

For the handling of the lock gate leaves, as well as for other Canal requirements, and commercial and general wrecking purposes, two powerful floating cranes have been purchased. For handling vessels of the largest size at Cristobal and Balboa, four high-power harbor tugs will be provided, and for the transportation of coal, fuel oil, and fresh water alongside of vessels, a sufficient number of barges and lighters will be placed in service. The steel barges, now in use by the Canal Commission, can be used to good advantage, after the necessary modifications have been made, in the barge and lighter service. A tender for passengers and mail will be furnished at each terminus also, provided the business justifies it.

The new or relocated line of the Panama railroad is 47.11 miles long, or 739 feet longer than the old line. From Colon to Mindi, 4.17 miles, and from Corozal to Panama, 2.83 miles, the old line is used, but the remaining 40 miles is new road. From Mindi to Gatun, the railroad runs, in general, parallel to the Canal, and ascends from a few feet above tidewater elevation to 95 feet above. At Gatun, the road leaves the vicinity of the Canal and turns east along Gatun Ridge to a point about 4½ miles from the center line of the Canal, where it turns southward again and crosses the low Gatun Valley to Monte Lirio, from which point it skirts the east shore of Gatun Lake to the beginning of the Culebra Cut at Bas Obispo. In the Gatun Valley section there are several immense embankments necessary to place the line above the lake level, which in the 3-mile section, aggregate about 5,000,000 cubic yards. Likewise, near the north end of Culebra Cut, where the line was located so as to furnish waste dumps for spoil from the Canal, there are several very heavy embankments. Originally it was intended to carry the railroad through Culebra Cut on a 40-foot berm along the east side, 10 feet above the water level, but the numerous slides made this plan impracticable and a line was constructed, on a high level around the Cut, known locally as the Gold Hill Line. Leaving the berm of the Canal at Bas Obispo, the Gold Hill Line cuts through a ridge of solid rock, and gradually works into the foothills, reaching a distance from the center line of the Canal of 2 miles opposite Culebra; thence it runs down the Pedro Miguel Valley to Paraiso, where it is only 800 feet from the center line of the Canal. This section of the line is located on a maximum grade of 1¼ per cent, compensated, and has a total length of 9⅜ miles. The sharpest curve on the whole line is 7°. From the south end of Culebra Cut at Paraiso, the railroad runs practically parallel with the Canal to Panama, with maximum grade of 0.45 per cent. Where the railroad crosses the Gatun River, near Monte Lirio, a steel girder bridge has been erected, the center span of which is in the form of a lift, to permit access to the upper arm of Gatun Lake. The Chagres River at Gamboa is crossed on a steel-girder bridge, ¼ mile long, with one 200-foot through truss channel span. Numerous other rivers and small streams are crossed on reinforced concrete culverts. Near Miraflores, a tunnel 736 feet long has been built through a hill. The total cost of the new line was $8,866,392.02.

CANAL SERVICE.

Steamshovels:		
105-ton, 5 cubic yard dippers	15	
95-ton, 4 and 5 cubic yard dippers	30	
70-ton, 2½ and 3 cubic yard dippers	33	
66-ton, 2½ cubic yard dippers	10	
45-ton, 1¾ cubic yard dippers	11	
26-ton	1	
Trenching shovel, ¾ cubic yard dipper	1	
Total		101
Locomotives:		
American—		
106-tons	100	
105 tons	41	
117 tons	20	
Total		161
French		104
Narrow gage, American, 16 tons		33
Electric		9
Total		307
Drills:		
Mechanical churn, or well	196	
Tripod	357	
Total		553
Cars:		
Flat, used with unloading plows	1,760	
Steel dumps, large	596	
Steel dumps, small	1,207	
Ballast dumps	24	
Steel flats	487	
Narrow gage	209	
Motor	6	
Pay car	1	
Pay certificate	1	
Automatic, electric	45	
Decauville	224	
Special, shops	12	
Total		4,572
Spreaders		26
Track shifters		9
Unloaders		30
Piledrivers		14

Dredges:		
French ladder	7	
Dipper	3	
Pipeline	7	
Seagoing suction	2	
Clamshell	1	
Total		20
Cranes		47
Rock breaker		1
Tugs		11
Towboat		1
House boats		3
Clapets		12
Piledriver, floating		3
Crane boat		1
Barges, lighters, and scows		72
Launches		29
Drill boats		2
Floating derricks		2

PANAMA RAILROAD.

Locomotives:		
Road, (12 oil burners)	36	
Switch	26	
Total		62
Cars:		
Coaches	57	
Freight	1,434	
Total		1,491
Cranes:		
Locomotive	2	
Wrecking	2	
Total		4
Piledrivers:		
Track	1	
Floating	1	
Total		2
Tugboat		1
Lighters:		
Coal, all steel	5	
Cargo, steel and iron	8	
Total		13
Motor boats		2
Steam ditcher		1

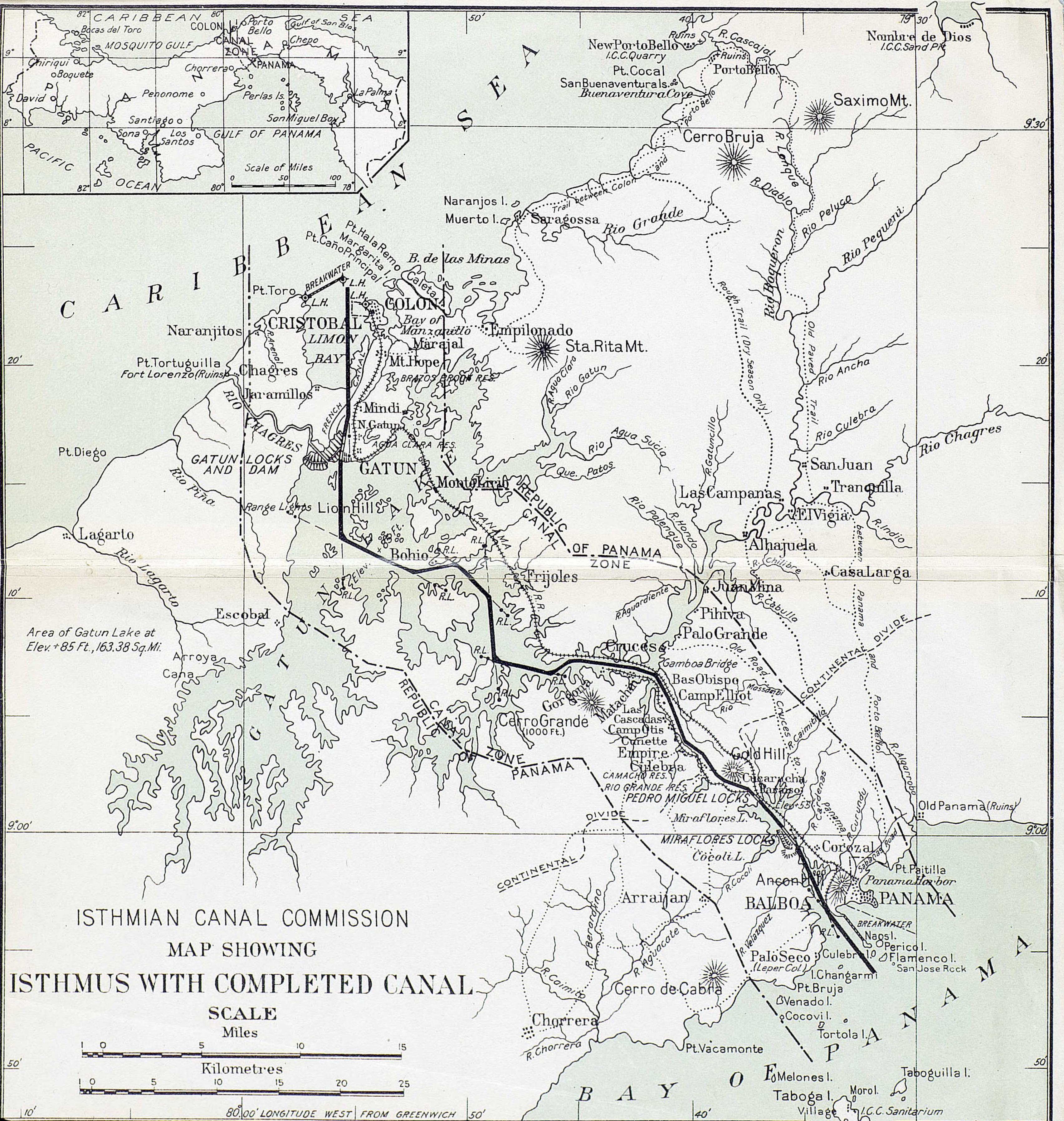
SAVED FROM NEW YORK VIA THE PANAMA CANAL ON TRADE ROUTES.

San Francisco:	
Magellan	13,135
Panama	5,262
Saved	7,873
Guayaquil:	
Magellan	10,215
Panama	2,810
Saved	7,405
Callao:	
Magellan	9,613
Panama	3,363
Saved	6,250
Iquique:	
Magellan	9,143
Panama	4,004
Saved	5,139
Valparaiso:	
Magellan	8,380
Panama	4,633
Saved	3,747
Honolulu:	
Magellan	13,312
Panama	6,700
Saved	6,612
Manila:	
Suez	11,589
*Panama	11,548
Saved	41
Yokohama:	
Suez	13,079
*Panama	9,798
Saved	3,281

Hongkong:	
Suez	11,628
*Panama	11,383
Saved	245
Melbourne:	
Magellan	12,852
Panama	10,030
Saved	2,822

*Via San Francisco and the Great Circle.

○



ISTHMIAN CANAL COMMISSION
MAP SHOWING
ISTHMUS WITH COMPLETED CANAL
SCALE
Miles
Kilometres
80°00' LONGITUDE WEST FROM GREENWICH
CARIBBEAN SEA
BAY OF PANAMA
CANAL ZONE
REPUBLIC OF PANAMA
CONTINENTAL DIVIDE
GATUN LAKE
Area of Gatun Lake at Elev. +85 Ft., 163.38 Sq. Mi.
COLON
CRISTOBAL
LIMON BAY
BREAKWATER
Pt. Toro
Naranjitos
Pt. Tortuguilla
Fort Lorenzo (Ruins)
Chagres
Jaramillos
RIO CHAGRES
GATUN LOCKS AND DAM
GATUN
Pt. Diego
Rio Piña
Range Lights
Lion Hill
Lagarto
Rio Lagarto
Escobal
Arroya Cana
Bohio
Frijoles
Monte Lirio
Mindi
N. Gatun
Mt. Hope
Marajal
Bay of Manzanillo
B. de las Minas
Caleta
Pt. Hala Remo
Margarita I.
Pt. Caño Principal
Empilonado
Sta. Rita Mt.
Naranjos I.
Muerto I.
Saragossa
Rio Grande
Trail between Colon and Porto Bello
New Porto Bello
I.C.C. Quarry
Pt. Cocal
San Buenaventura Is.
Buenaventura Cove
Porto Bello
R. Cascajal
Nombre de Dios
I.C.C. Sand Pit
Saximo Mt.
Cerro Bruja
R. Longue
R. Diablo
Rio Boqueron
Rio Peluca
Rio Pequeni
Rio Gatun
Rio Agua Clara
Rio Agua Sucia
Que. Patos
Rio Gatuncillo
Rio Palenque
Rio Hondo
South Trail (Dry Season Only)
Old Paved Trail
Rio Ancha
Rio Culebra
Rio Chagres
San Juan
Tranquilla
Las Campanas
El Vigia
R. Indio
Alhajuela
R. Chilibre
Casa Larga
Juan Mina
R. Aguardiente
Pihiva
Palo Grande
R. Cabullo
Old Road between Panama and Porto Bello
Cruces
Gamboa Bridge
Bas Obispo
Camp Elliot
Gorgona
Matachin
Las Cascadas
Camp Otis
Cunette
Empire
Culebra
Cerro Grande (1000 Ft.)
Gold Hill
Cucaracha
Paraiso
Elev. +55
CAMACHO RES.
RIO GRANDE RES.
PEDRO MIGUEL LOCKS
Miraflores L.
MIRAFLORES LOCKS
Cocoli L.
R. Cocoli
Corozal
Sabanas Road
R. Algarrobo
Old Panama (Ruins)
Pt. Paitilla
Panama Harbor
PANAMA
Ancon
BALBOA
Naos I.
Perico I.
Flamenco I.
San Jose Rock
Culebra I.
Arraijan
R. Velazquez
Palo Seco (Leper Col.)
I. Changarmi
Pt. Bruja
Venado I.
Cocovi I.
Tortola I.
R. Aguacate
R. Berardino
R. Caimito
Cerro de Cabra
Chorrera
R. Chorrera
Pt. Vacamonte
Melones I.
Taboga I.
Moro I.
Village
I.C.C. Sanitarium
Taboguilla I.
CARIBBEAN SEA
COLON
Porto Bello
Gulf of San Blas
Bocas del Toro
MOSQUITO GULF
CANAL ZONE
Chepo
Chiriqui
Boquete
Chorrera
PANAMA
David
Penonome
Perlas Is.
La Palma
Santiago
San Miguel Bay
Sona
Los Santos
GULF OF PANAMA
PACIFIC OCEAN
Scale of Miles