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THE PANAMA CANAL IN 1908.*

By VAUGHAN CORNISH, D.Sc., F.R.G.S., F.G.S., F.C.S., M.J.S.

HAVING first visited the Canal Works at the beginning of January, 1907, I decided to make a careful study of the undertaking, but the work was interrupted by the earthquake which I experienced at Kingston on the 14th. The investigation of this phenomenon occupied me for the rest of the year, and it was not until 1908 that I was able to resume the study of the Canal Works. For this purpose I visited Washington, and made application through the proper channel to the Department of State, who kindly consented to further the inquiry. I proceeded then from New York to the Isthmus by the R.M.S.P. *Magdalena*, arriving at Colon April 12, 1908. Here Colonel Goethals, chairman of the Isthmian Canal Commission, provided me with a letter to those concerned to furnish all information, and proposed that I should make my way about unattended, and pursue my inquiries independently, which I did. I spent rather more than a fortnight on the Isthmus, daily inspecting the works and interviewing the *personnel*, and I shall always look back on this time as one of the most interesting and delightful in my life. Alike for the student of science and of affairs, there is at present no place more interesting than the Isthmus of Panama.

The locus of the canal is the central line of a strip 10 miles wide, called the Canal Zone, which extends from the Bay of Limon on the Atlantic to the Bay of Panama on the Pacific ocean, and for about 3 miles seawards in both oceans, the group of islands in the Bay of Panama being also included therein.

The occupation and control of the Canal Zone has been acquired by the United States in perpetuity from the State of Panama, a republic, constituted in 1904, whose independence is guaranteed by the United States.

By the Hay-Pauncefote treaty of 1901 between Great Britain and the United States, it is enacted that the proposed canal shall be open on equal terms to the ships of war and commerce of all nations, both in time of peace and in time of war. The canal, however, although in this sense neutral, is national, not international. It is to be operated solely by American citizens, fortifications are to be erected, and its defence will be undertaken by the army and navy of the United States.

The unfinished works of the French companies having been acquired

* Read at the Royal Geographical Society, November 30, 1908. Illustrated by photographs by the author. Map, p. 240.

by purchase, and the treaty with the Republic of Panama having been ratified, the Americans started work in June, 1904.

SANITATION ON THE ISTHMUS.

In July, 1904, Colonel W. C. Gorgas, M.D., took charge of the Department of Sanitation, which he has administered ever since to the great benefit of all concerned.

Natives of the Zone and West Indian negroes are immune from yellow fever, but this swiftly fatal disease has invariably broken out on the Isthmus when a large number of non-immune strangers have gathered there. An outbreak occurred in April, 1905, and soon produced a panic which threatened to bring the whole undertaking to an untimely end.* Heroic measures were adopted; the force of the Sanitation Department was increased to four thousand men; the city of Panama was cleansed and fumigated house by house, the *stegomyia* mosquito which propagates the disease was exterminated, and the epidemic ceased. Finally, the city of Panama was provided with a proper water-supply, was brick-paved, sewerred, and plumbed, and there has been no return of the disease. Similar measures have been taken in Colon.

Anopheles, the mosquito of malaria, which breeds on fresh water where grass and algæ grow, is prevalent all across the Isthmus; whereas the yellow-fever mosquito is chiefly confined to the neighbourhood of towns. Protection from malaria is afforded by housing employees in buildings screened by copper gauze, and by oiling or draining stagnant waters. The final method is subsoil draining,† for open channels are liable to be temporarily blocked, forming pools in which water remains stagnant sufficiently long for the larvæ to be deposited and hatched. By these means, and by the supply of quinine, malarial fever has now been so far reduced that it no longer seriously hampers work.

In 1907 the total death-rate among employees from all causes, including accident, was—

				Average number.	Total deaths.	Annual death- rate per thousand.
White employees	...	...	...	10,709	179	16.71
Black „	...	...	...	28,634	953	33.28
Total	...	...	...	39,343	1,132	28.77

* *Vide* 'I.C.C. Annual Report, 1905,' p. 30; and Colonel Gorgas on "Sanitation in the Canal Zone," *Journ. Am. Med. Assoc.*, July 6, 1907, vol. 49.

† Until the Lincolnshire fens were drained *malaria* was common in that part of England, where it was known by the name of ague.

During the same period, among 1337 American women and children in Commission quarters there occurred nine deaths, an average of 6.73 per thousand.

Modern science, in conjunction with a despotic government, for such in fact is the Canal Commission, has proved equal to the task of tropical sanitation on the Isthmus.

ON THE TYPE OF CANAL.

While the doctors were fighting the battle of sanitation, the Government of the United States was engaged upon the almost equally anxious task of deciding whether the canal was to be tide-level or high level. The Isthmus of Panama is so hilly that, unless by tunnelling, a shipway can only be constructed by following as far as possible the river valleys. That of the Chagres leads from Colon for 26 miles directly towards the Pacific ocean. At or near Bas Obispo the course of the valley abruptly turns, running parallel to the coast. A distance of only about 9 miles separates this place from the low valley of the Rio Grande, which leads directly to the Pacific. This is the route chosen for the canal. But where the upper Chagres meets the line of the proposed canal its surface is 46 feet above tide-level in the dry season, and sometimes 80 feet above during floods. If, therefore, a tide-level canal be made, the waters of the Chagres must either be directed into another channel or controlled in their passage through the canal. In either case the difficulty of the task is much enhanced by the sudden floods to which this considerable river is subject. The same remarks apply to the other rivers on both banks of the canal and on both sides of the divide. The original scheme of De Lesseps would have involved practically three waterways, of which the middle one would have been for navigation, and it would for a great part of its course have been threatened by the higher waters of the artificial river-channels on either side.

The tide-level scheme of the majority-report of the Board of Consulting Engineers appointed by President Roosevelt was different. They recommended a dam at Gamboa to control the upper waters of the Chagres. Their flow through the canal would be so regulated that the currents would not prevent navigation. Other dams and some diversion channels would be made to control the lower waters of the Chagres and other rivers. The Gamboa dam, dealing with the upper waters of the Chagres, was, however, the salient feature of the scheme. It was admitted that the tide-level canal would cost more and take longer to build than a high-level canal, but it was claimed that it would have (in addition to the other advantages entailed by the absence of lift-locks) the great merit of being less liable to damage and obstruction in case of hostilities.

The disadvantage of slow construction was considered, however, to be fatal, and the Administration accepted the view of other experts that

the time estimated by the majority of the Board was inadequate for the completion of the tide-level canal, and that the currents would be a source of trouble. Considerations of cost appear to have had less weight than that of delay, but account was also taken of them and they were also against the tide-level scheme.

In 1906, therefore, an Act of Congress was passed sanctioning the 85-foot-level scheme. By the previous "Spooner" Act of 1902, it was enacted that the canal should be such as would provide a passage for the largest ships built or such as might reasonably be expected to be built. Thus the depth of the canal and the dimensions of the locks had necessarily to be much greater than had been contemplated in the high-level scheme which was the later scheme of the French engineers.

The salient feature of the 85-foot-level scheme is the great dam which is to pond back the lower as well as the upper Chagres and all its tributaries in the manner shown on the map. The "Lake Gatun" thus formed will have an area of 164 square miles, *i.e.* twice that of the Lago Maggiore. By means of this dam the streams will be tamed, and a waterway provided which will be broad and easy of navigation for many miles.

Unfortunately, however, the site for the dam, and all other possible sites for such a dam, do not admit of a foundation on hard rock. The Gatun dam is not only to be itself composed of loose material, but is founded partly upon clay and partly upon sand and gravel. The Gamboa dam, on the other hand, would have been founded upon hard rock and could have been built up therefrom in solid masonry, thus forming part and parcel of the stony framework of the globe itself.

THE HIGH-LEVEL CANAL AS IT IS TO BE.

From shore to shore the canal is 41 miles long, but to reach deep water 4 miles must be dredged at either end, so that the whole length is 49 miles; of this about 9 miles has to be excavated in hard rock.

The Spooner Act, the law under which the canal is being constructed, enacts that it shall be "of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draught now in use, and such as may reasonably be expected." Accordingly, the following dimensions have been selected:—

First, a minimum depth of 41 feet.

Secondly, a minimum bottom width of 200 feet in the Culebra cut.

Thirdly, each lock will have a usable length of 1000 feet and a width of 110 feet.

Fourthly, the minimum radius of the curves is 5577 feet (1700 metres).^{*} This curve, however, does not come in the Culebra cut

^{*} *Vide* p. 205 of Gen. Abbot's 'Problems of the Panama Canal' (1907). Slight changes in the projected course are made from time to time, so that this figure is subject to some modification.

SITE OF GATUN LOCKS AND DAM, LOOKING WEST.

LOCK SITE AT GATUN, LOOKING NORTH.

where the bottom width is to be 200 feet, but north of Bas Obispo where the bottom width is 500 feet. Most of the curves have a radius of 9842 feet (3000 metres).

A reference to the accompanying map will show that most of the curves are situate in Gatun lake, where the width of the canal proper is large, and where the spread of shallower waters secures better steerage.

Thus the high-level canal is not only deep and wide, but also much freer from troublesome curves than might be supposed from a casual inspection of its course. The details of the bottom width of the high-level canal in its different parts are as follows:—

From the Atlantic entrance to Juan Grande (27 miles)	...	...	1000 feet.
Juan Grande to Bas Obispo	...	...	500 "
Bas Obispo to a point about half-way between Empire and Culebra	...	...	300 "
Culebra cut, nearly to Pedro Miguel lock (about 4 miles)	...	...	200 "
Pedro Miguel to Pacific entrance	...	...	500 "

The length and width of the locks has already been stated. The maximum lift will be 32 feet, or about 4 feet more than in any other locks at present in use. As the width (110 feet) is much greater than that of existing locks, it follows that the lock gates will be far larger than any now in use. A vessel has to pass through a flight of three succeeding locks at Gatun. Parallel with this is a second flight of three locks, so that two ships could be simultaneously put through either flight in the same, or in opposite, directions.

It is hoped to accomplish the whole transit in eight or ten hours. On this basis it is calculated that forty ships could be put through in twenty-four hours from the Atlantic to the Pacific, or two fleets of twenty ships if passing simultaneously in opposite directions.

At Pedro Miguel the vessel passes through one lock on her way down to the Pacific, and at Milaflores through two locks. Each of these three locks has a duplicate alongside, permitting, as at Gatun, the simultaneous passage of a companion vessel, or of one going in the opposite direction.

The lift of the lower lock at Milaflores is variable, depending upon the level of the tidal water in the last reach of the canal. The extreme range of the tide at La Boca, the Pacific entrance to the canal, is 20 feet, that is to say, low water during "spring" tides is 10 feet below the average sea-level. During low tide on the Pacific side, therefore, the water in the canal stands 95, instead of 85, feet above that sea. The sea on the Atlantic side is practically tideless.

Beyond Milaflores locks the vessel enters a reach of the canal which is exposed to the ebb and flow of the tide, and *which will be confined within banks or levees as far as La Boca*. In this respect the plan and the profile are, unfortunately, misleading. The La Boca lock and dam have been abandoned, and no Sosa lake will therefore come into

existence, the lowest locks being, as I have said, at Milaflores. I have thought it better to reproduce the existing maps as they stand, rather than to attempt a redraught, which would necessarily be imperfect. The vessel, then, below Milaflores is in a tidal channel, and will be subject to some tidal current. By designing this channel so as to avoid a bottle-neck, and by giving it a width of 500 feet, the calculated current will, however, not exceed 1 foot per second.

It will be seen from the plan that the dredged sea-channel by which the vessel will reach deep water on the Pacific, passes to the west of the Isle of Naos, instead of to the east, as was proposed in the earlier plans. Such will be the navigation of the canal. I proceed to deal with the most important points relating to its locks and dams.

The mitre sill of the top lock at Gatun is 37 feet above mean sea-level, and, if the locks were broken, there would remain 32 feet of water above the dam. Above the Pedro Miguel and Milaflores locks there is not the same surplus depth of water.

Dams have to be constructed in the vicinity of the locks at Pedro Miguel and Milaflores. At both places the dams will be short, and will be founded upon hard rock,* and in each case the head of water to be held up will only be about 40 feet instead of 86, as at Gatun. The construction of the dams at Pedro Miguel and Milaflores is not, therefore, regarded with anxiety.

The great Gatun dam remains the one important experiment in the scheme of the high-level canal, and much attention is being devoted to the planning of this work. The alluvial foundation is a disadvantage shared by the Bohio site formerly chosen, and all other sites in the lower Chagres valley; so that, having decided upon the Panama route and a high-level canal, there appears to be no alternative to the construction of a dam upon this kind of bottom. The details of the proposed structure as elaborated in April, 1908, were as follows:—

The length of the great earthen dam is 7700 feet; its breadth no less than 2060 feet. The weight of the dam per linear foot is more than sixty times the horizontal pressure of the water in the lake, so that the pressure could not move the whole mass; and the weight of the dam is spread over such a great width that it is not thought that the ground will sink beneath it. The form of the section is shown beside the map of the canal zone, and an idea of the topography may be obtained from the photograph on p. 157, which I took in April, 1908. The eastern end of the dam abuts on the hill of hard, fine-grained argillaceous sandstone in which the lock-site is being excavated.

The dam, according to present plans, is not to be merely superposed upon the surface as originally proposed in 1905. Embedded in its

* 'Canal Zone Pilot,' pp. 316, 317.

earthy mass there is to be a puddled core, and a trench will be excavated to a level of 40 feet below the sea (-40 feet) for the lower part of this core. Nor is this all that is to be done to check seepage beneath the earthen dam. From the bottom of the trench excavated for the puddled core, sheet-piling, made of 4-inch timbers, is to be driven down for another 40 feet, so that sheet-piling and puddled core together will form an impervious barrier to -80 feet; that is to say, 80 feet below the surface-level of the sea, or about 85 feet below the lowest natural surface of the ground. The puddled core is carried up through the earthen dam to the level of $+90$; that is to say, 5 feet above the level of the lake, which is to be 85 feet above sea. The crest of the dam will be $+135$ feet, *i.e.* 50 feet above the level of the lake; this excess of height being to provide top weight for increased stability of the whole structure, and also for the purpose of compacting the underlying material. The under-water slopes of the earthy materials have been reduced from 1 : 3 of the 1905 plan, to 1 : 5. On the other hand, it has been decided that the width of 2625 feet given in 1905 was in excess of utility, and that a reduction of between 500 and 600 feet can be made without loss of strength or efficiency.

About half-way across the valley occurs a low hill, on which a house is shown in the photograph. This hill is on the crest-line of the dam, and is useful as giving support to the sides of the regulating channel which will be excavated in it. The material of the hill, however, is not the hard argillaceous sandstone of the lock-site, but merely alluvial. The regulating works themselves will be built of concrete, a solid mass built up to $+69$ feet, and on this piers will be constructed 8 feet in thickness, between which will be the sluice-gates. By their means the level of the lake will be prevented from rising unduly in flood time.

The capability of the dam to maintain the waters of the lake at a sufficient level in the dry season depends upon their not finding a ready way, either through the dam itself or below it. The construction of the dam is believed to guarantee its own practical impermeability. Not only is there a puddled core, but the soil, sand, and rocks of which the principal mass will be composed, will be laid down in the manner best calculated to secure compactness. With regard to underground flow, there is, across most of the valley, a bed of indurated clay which is regarded as sufficiently impervious, and wherever the puddled core and piling are embedded in that clay, it may, I think, be assumed with some confidence that the leakage will be unimportant. On referring to the section showing borings (see map), however, it will be seen that there are in the valley two old river-gorges which, to a depth of 200 and 260 feet, are filled only with gravel, sand; sand, shells, and wood; clayey sand; and so forth. These gorges, measured on the section shown, have widths of about 1200 and 500 feet respectively at the depth

to which the sheet-piling goes, and extend about 120 and 180 feet below it. How much water may escape by these gorges it is difficult, indeed, I think, impossible, to say.

ON THE SUPPLY OF WATER AVAILABLE FOR THE NEEDS OF THE HIGH-LEVEL CANAL.

The construction of the Suez canal was a work of excavation pure and simple. The construction of any kind of canal across the Isthmus of Panama involves another task, second only in importance to the primary work of excavation, viz. that of controlling the rivers.

In the case of a sea-level canal the problem would have been, how to get rid of their waters, particularly in the rainy season.

In the actual case of an 85-foot-level canal, the regulation of the rivers, particularly of the Chagres, presents two aspects, viz.—

(1) In the wet season, disposing of the surplus waters.

(2) In the dry season, conserving water supplied by the rains so as to meet the waste caused (*a*) by locking, (*b*) by evaporation, (*c*) by percolation or other underground flow.

The arrangements for taming the Chagres and its tributaries have already been described. They are, briefly, the construction of the Gatun dam and its spillway. But for a high-level canal it is equally important that there should be sufficient water in the dry season.

Probably there is no problem of the Panama canal which has received more prolonged and careful study than this,* and from the data obtained the authorities are confident of an adequate supply. Yet whatever depends upon climate is liable to unexpected accidents, and I regard as an important safeguard the fact that at Alhajuela, on the Chagres, 9 or 10 miles above Obispo, there is an excellent site for a dam which would form a reservoir where some of the surplus water of the wet season could be stored, and supplied to the canal as required. The details for such a dam were elaborated in connection with one of the earlier plans of the canal, so that the necessary data would be immediately available in case its construction should become necessary in the future. This is especially important in view of the possibility of leakage from the Gatun lake.

ON THE PRESENT CONDITION OF THE CULEBRA CUT, AND ON THE METHODS EMPLOYED FOR EXCAVATION AND DISPOSAL OF THE SPOIL.

Reference once more to the plan and profile will show at a glance the length and position of the rocky divide, the whole of which is termed the "Culebra Cut," from the name of the town near the highest point. The proposed form and dimensions of this cut throughout the

* See 'Problems of the Panama Canal,' by Brigadier-General Henry L. Abbot, late Corps of Engineers, U.S.A.

THE CUT AT CULEBRA, LOOKING NORTH-WEST.

THE CUT AT CULEBRA, LOOKING SOUTH-EAST.

5 miles of greatest depth is shown beside the map, this being the cross-section adopted at the commencement of 1906, and the stage reached in April, 1908, is shown by the photographs on p. 163. The line drawn across the above section at a level of 120 feet above bottom (160 feet above sea) shows the general level of the bottom of the workings at Culebra itself at the time when the photographs were taken. A narrow pilot cut, only, was then 20 feet lower. All that part of the section below this line (+160) remained to be excavated. Most of the rock above this line has been removed, but not all, for the final width is not, of course, reached at any level until the central portion has been excavated below that level.

The level of the original rock-line shown in this section was +275, *i.e.* 235 above canal bottom, so that the photographs show excavation of 115 feet of rock. There was, however, soil above the hard basaltic rock, of varying thickness, removed to the slope 1:2, as shown on the section. The highest original surface of the soil on the centre line of the canal (between Golden hill and Silver hill at Culebra) was +312 feet, so that the photographs in which Golden hill appears show a total excavation of 152 feet along the centre line. As this line passed along a saddle between the two hills the original surface at the sides was considerably higher, so that the total height from the bottom of the cut to the highest berm, or ledge, on Golden hill is considerably more than 152 feet.

The bottom of the canal will be 272 feet below the original saddle, and its depth below this berm is considerably more.

Thus will the gorge appear when the excavation is finished and before the water is allowed to flow in. When full, the surface of the water will be 227 feet below the original saddle, and the passenger on a vessel will gaze upon the scarped banks of a somewhat greater height than this.

For a tide-level canal not only would the depth be 85 feet greater, but, as the slope could not be made steeper, the width of the whole cutting would be correspondingly increased.

With reference to the slope of the sides it is important to note that it has not been found practicable to adhere always to the proposed section, which has to be made flatter, thus considerably increasing the amount of excavation required. Soil-slides in the wet season are a great hindrance, especially at Cucuracha.

Alighting at Culebra station on the Panama railway and proceeding to the western side of the cut, one obtains the most impressive view of the canal works, and this is the spot usually visited by travellers. I first stood there in January, 1907, and returned in April, 1908. The impressions obtained were very different on these two occasions. In January, 1907, after two-and-half years of American occupation, what struck me most was the enormous mass of material which had been

removed by the French companies, and the comparatively insignificant appearance of the American excavations, which could readily be distinguished from the older work already coated with vegetation. It was then that I began to appreciate the heroic labours of the French engineers, whose achievements under circumstances of great difficulty are being daily more and more appreciated and praised by their successors. Turning to study the progress of the work, I watched with delight the operations of the 100-ton steam shovels which, at a distance, when the human hands are not seen, appear endowed with volition. The cars were loaded with surprising celerity and the dirt-train was hauled off to the distant dump by an old Belgian locomotive, part of the machinery taken over from the New Company. But then the hitch came—there were no cars to take the place of those already filled, and the steam-shovel was idle. Looking round I found that many other steam shovels and their crews were idle from the same cause, the machinery for transportation not having been provided in proper proportion to the machinery of excavation. That the time required for the completion of the rock-cut was limited by the possible rate of transportation of spoil, and not by that of excavation, had long been known, and the report of the Board of Consulting Engineers contains elaborate diagrams of space available for shovels and tracks. It was apparent, therefore, that the organization of the work was not yet perfected.

While, however, the fighting force, so to speak, of the Isthmian army was obviously imperfect in many respects, great results had evidently been achieved by the auxiliary services. The Department of Sanitation had already made the Isthmus healthier than most equatorial countries. Food and quarters were excellent; law and order were well maintained.

On the first day of my second and prolonged visit—April, 1908, fifteen months later—I went at once to the same spot on the Culebra cut, opposite to Golden hill, and again surveyed the scene of operations. The change was enormous. The gorge below me was greatly enlarged, the shape of the hills altered, the face of the landscape changed. As I gazed into the deep trench below, the thought flashed across my mind, If my life be spared a few years longer, I will sail through this on a ship.

The reason of the great change was readily apparent. Organization had now been perfected. In the first place, the whole width of the cut was laid down in railway tracks, tier above tier at the different levels, so that the view was like the approach to the metropolitan terminus of one of the world's great railways. Up and down these tracks there came and went without ceasing the spoil-trains, now composed of larger trucks than formerly, with new and ingenious devices for rapid unloading. The number of steam shovels visible was much larger than in 1906; yet they were kept constantly busy, and all the time the drilling machines were at work, boring holes for charges of dynamite, and gangs of men were completing the preparations for explosions in other holes

already completed. Yet if the eyes were raised for a moment from the busy scene below, they rested on a silent wilderness of tropical forest, stretching unbroken to the horizon. I stayed until, at the approach of sunset, the work of the shovels ceased, and hundreds of men swarmed out of the cut and sought their quarters and the evening meal. But all was not over for the day, for now, when the cut was cleared, the shot-firing began. At intervals there occurred a deafening explosion; the earth trembled as in a considerable but preternaturally short earthquake, and masses of rock rolled down the slopes, disintegrated, and ready for the shovel-man when he should arrive next morning. I paid many visits to the cut between Empire and Pedro Miguel, but oftenest at Culebra itself. The sight never palls, and is one of the wonders of the world.

During the day the spoil-trains follow one another at intervals of about three minutes, and if, from any cause, delay occur, the steam shovels, and indeed the whole process of excavation, is brought to a standstill. Any cause of delay is therefore reported at once by telephone to the Superintendent of Transportation at Empire, and all energies are at once directed to clearing the way. On the Isthmus everything gives way to the "dirt" train, as it is usually called. It is this dirt which stands between the American nation and the realization of their long-cherished scheme, and nowhere is the classical definition of dirt as "matter in the wrong place" so appropriate as on the Isthmus.

Let us now see how much matter has been removed, and how much dirt remains which has yet to be removed. I will give first the totals of what has been got out in both dry and wet way, both in the canal prism itself and for auxiliary works.

TOTAL EXCAVATION IN CONNECTION WITH THE PANAMA CANAL.*

By the French companies about	...	...	81,548,000 cubic yards.
By the American Isthmian Canal Com-	...	...	...
mission up to the end of June, 1908	...	40,923,533	" "
		<hr/>	
		122,471,533	

Much of the work of the French companies, however, consisted in dredging out sea-level channels at both ends of the canal, whereas the principal American work has been rock excavation in the Culebra cut—or *the* cut as it might equally well be called. The figures relating to the cut are—

EXCAVATION BETWEEN BAS OBISPO AND PEDRO MIGUEL, *i.e.* "THE
CULEBRA CUT," 9½ MILES.†

By the French companies	...	...	22,600,000 cubic yards.
By the American commission to end of	...	...	...
June, 1908	...	20,125,185	" "
Total excavated in the cut	...	42,725,185	" "
Remaining to be excavated	...	37,973,063	" "

* *Canal Record*, July 8, 1908.

† *Ibid.*, August 12, 1908, and July 8.

so that at the end of last June the cut was half cut through, one quarter having been done by the French companies and one quarter by the American Commission.*

This statement by itself, however, would give an inadequate idea of the rate at which the excavation is now proceeding, for of the total taken out of the canal prism in the cut since 1904, more than one-half was the work of the twelve months prior to June last, and the rate of progress is now even greater than in the year June, 1907—May, 1908.

On the Date of Completion of the Canal.—Colonel Goethals, Chief of the Commission, when examined early in 1908 at Washington, declined to bind himself to a date for completion, or to an estimate of cost; nevertheless it is not difficult to calculate the date of completion from the actual rate of progress on the assumption that all goes well. The year 1915 is thus arrived at by the authorities for the calculated, though not promised, completion. This is based primarily upon the rate of excavation possible under the restrictions imposed by the narrow gorge along which the spoil has to be transported. It has been also calculated that the constructive works, the locks and dams, would require about the same time as, but not longer than, the excavations. This proper balance between the time required for the two elements, excavation and building, was one of the arguments employed in favour of the 85-foot-level canal, as securing "the utmost practicable speed of construction"† which could be obtained in a canal "affording convenient passage for vessels of the largest tonnage."

LABOUR ON THE ISTHMUS.

West Indian Labour.

The success of sanitation, and the modern facilities for storage of food, have greatly simplified the task of obtaining an adequate supply of navvies for the pick and spade work. At first the commission relied almost entirely upon the West Indian negro, who formed the majority of the navvies employed under the French companies. The commission, however, were profoundly dissatisfied with the result, and reported that the negroes seemed to be disqualified from doing satisfactory work by lack of actual vitality.‡

Nevertheless, they are still employed in undiminished numbers on the Isthmus. The lack of strength was found to be due largely to improper diet, and most of the West Indians are now provided with proper cooked meals, as is done in the case of American and European employees. In order to ensure their profiting by this provision, however, the charge

* The total excavation for the prism of a sea-level canal was calculated by the Board of Consulting Engineers at 231,026,477 cubic yards.

† See address by President Roosevelt to Board of Consulting Engineers, September 11, 1905, "Report of the Board," p. 12.

‡ "Report," December, 1906.

for meals in the case of West Indians is deducted from wages. The result of supplying a nourishing diet has been a marked increase in working strength as shown by output.

Although the climate and products of the Isthmus are so similar to those of their own islands, comparatively few of these employees settle there, but return to the homes they love so well. It is gratifying to an Englishman to find that those who come from the British islands are proud of their citizenship and pleased to greet him as a fellow-subject.

The ordinary West Indian labourer receives 10 cents gold (about 5*d.*) per hour and free quarters. Deducting the 30 cents *per diem* charged for meals, he receives 50 cents (2*s.* 1*d.*) for an eight-hour day, besides food and lodging.

The total number actually at work on the Isthmus on certain days has been—

June 30, 1907.							
On the canal works	...	...	...	...	...	...	14,606
On the Panama railroad	...	...	...	...	...	...	4,979
Total							19,585

and on June 30, 1908, the number on the canal works alone was 16,078.

The total number on the roll is of course considerably more than 20,000, as there are necessarily absentees every day owing to sickness, accident, or other cause.

European Labour on the Isthmus.

In 1906, the number of European labourers on the Isthmus was insignificant, and the commission, at the time profoundly dissatisfied with the West Indians, issued invitations for proposals to furnish 2500 Chinese labourers with the privilege of increasing the number to 15,000.* Nothing came of this scheme, however, while, on the other hand, the already improved, and still improving, conditions on the Isthmus enabled the commission to obtain a largely increased supply of European labour. While the supply of West Indians was maintained constant, or only slowly increased, the additional force required was therefore obtained from Europe. The following figures show this:—

EUROPEAN LABOURERS ACTUALLY AT WORK ON		
June 30, 1906.	June 30, 1907.	June 30, 1908.
500	4317	4913

The majority were from Greece, Italy, and Spain, each of these countries sending at first about the same number. The Greeks were considered to be physically inferior to the Italians and Spaniards, and

* Report of I.C. Commission, 1906, p. 14.

their number, in April, 1908, was only about 300. The Italians, physically excellent, and standing the climate well, were found somewhat intractable. A large proportion were migrant labourers who had become prone to collective action when dissatisfied, and their numbers in April, 1908, had been reduced to 500 or 600. The Spaniards, mainly Galicians and Castilians, were found to be equal to the Italians in physique and health, and to give far less trouble. The number employed in April, 1908, was about 5000, so that the Spaniards constituted about five-sixths of the European force, which numbered in all slightly over 6000. The figures given above for those at work on certain days are considerably less, there being always a number absent from one cause or another.

The Spaniards do not appear to be oppressed by working in the tropical heat—even at midday at about the hottest time of year. The ordinary European labourer, in addition to free quarters, receives 20 cents gold per hour, or \$1.60 per eight-hour day; more when working overtime. He is charged 40 cents per diem for his three meals, served in the European mess, which leaves \$1.20 as a *minimum* net wage per diem, or a little less than 30s. per week, but many earn more.

The Spaniard shows no sign of settling upon the Zone. Sometimes he goes on to railway work in Brazil, more often he returns home with his savings.

Skilled Labour on the Isthmus.

The skilled labour on the Isthmus has, from the outset, been mainly done by white Americans, but there are still, on the "Gold Roll," as it is termed, some Europeans. New rules reducing the maximum length of leave have, however, made these posts less attractive to those whose homes are at a greater distance, and by an order of February 8, 1908, all future appointments on the Gold Roll shall be American citizens, if the special services required can be obtained in the United States; and in the event of any reduction of force preference shall be given to American citizens.

An eight-hour day is established by law for employees on the Gold Roll, the quarters are excellent, and excellent meals are provided at a fixed charge in the commission's hotels.

I should like in this place to add a word of tribute to the great courtesy and kindness which the American mechanics show towards ladies, a circumstance which did much to render pleasant the excursions which my wife took on the Isthmus, sometimes in my company and sometimes alone.

In this connection, also, I must add a word upon the marvellous respectability of the Canal Zone, where nothing unseemly meets the eye. Taking all the circumstances into account, this is a state of things of which the American nation has reason to be proud.

The number of Americans on the Gold Roll in January, 1908, was about 6000, the total number of employees on the rolls of the commission and of the Panama railroad being then, approximately, 43,000. The total number of employees actually at work on January 29, 1908, was—

On the canal works, January 29, 1908	...	...	...	25,367
On the Panama railroad	...	...	...	6,557
Total	...	...	...	31,924

The Canal Zone now being healthy, the life of the Americans is a cheerful as well as a busy one. Not only do the men look well, but the women and children also.

The children are able to be in the open air all day, for sunstroke is rare on the Isthmus; they are bronzed and active, and apparently thoroughly satisfied with themselves and with their surroundings. Even when within doors they are still in a sense in the open air, for the windows are unglazed, and the houses are constructed so as to secure a free circulation of air.

The commission clubs for gold-employees at the principal stations are commodious structures, admirably designed for social recreation. Their management is entrusted to the Young Men's Christian Association. There are well-equipped reading and writing rooms and gymnasias, mainly used by the men; but the interests of the women and children are not neglected, and for the latter playrooms are provided. The large halls are used for entertainments and meetings. These clubs and other organizations for recreative pastimes have undoubtedly contributed to improve the general health of the community.

ON THE FUTURE OF THE WHITE RACE IN TROPICAL COUNTRIES.

The question whether the white race can make a home in the tropics depends largely upon the tropical baby; upon his own health, and that of his mother. The American occupation is still recent, but, as far as experience goes, it seems that the white children born on the Isthmus have not shown unusual delicacy, and the mothers have made a normal, though sometimes rather slow, recovery from confinement.

With regard to the possibilities of the tropics for the white race, I submit the following tentative conclusions, viz.—

That the debilitating effect which they have been observed to exercise upon those who come from temperate regions has been due mainly to the presence of certain diseases which can be done away with.

That the rapid deterioration of the white stock which is usually noticed in the tropics, especially near the equator, is largely due to the same cause.

But that Anglo-Saxons cannot perform nearly the same amount of hard bodily labour in a constantly hot climate as they can in the temperate zone, and Anglo-Saxon immigrants never will be able to do

so. In this, I think, the Mediterranean races, at all events the Spaniards and Italians, are our superiors.

Whether the descendants of Anglo-Saxon stock who have settled in a tropical country purified from tropical diseases will be able to support continued hard bodily labour better than their immigrant ancestors is a matter about which we have at present little direct evidence.

It is the case that in the tropics, particularly in the equable equatorial belt, many evils of the temperate zone are avoided, chiefly those due to cold and to sudden changes of temperature. It is this equatorial belt of equable temperature and heavy rainfall that I chiefly have in mind, for it comprises those vast regions of prolific vegetation which appear capable of supporting so large a population.

The white man already rules, or has marked off for rule, the whole of the equatorial belt, but who is to be the peasant cultivating this belt? In those parts of tropical Asia already peopled by industrious Orientals there can never be a white peasantry. Equatorial Africa presents great differences in different parts with respect to native population, and the question of a possible future for white peasantry is there a complicated one. In South America, however, there are vast equatorial regions either wholly unpeopled, or sparsely inhabited by tribes of that Indian stock which has elsewhere proved so slight an impediment to the establishment of the white labourer. Served by a system of rivers unrivalled elsewhere in equatorial regions, already partitioned among Christian governments, and for the most part uninhabited, equatorial South America offers the readiest field for the establishment on a vast scale of a white peasantry under the equator.

By clearing the scrub within 100 or 200 yards of his cottage, and by employing wire screens, the cultivator can protect himself against the malarial mosquito, and his crops come not once, but several times, a year.

If the Spanish, Portuguese, and Italian peasant were to turn his attention to this field, instead of, or in addition to, that of navvy work, great things might come of it. The circumstance that South America is a Roman Catholic continent, where the Latin races are dominant, would greatly favour the experiment. On the Zone the Spanish labourer works in order to save and to depart; the *milieu* being foreign to him and unattractive. In a Latin state it would be different.

I put these opinions forward with great diffidence, knowing that they differ somewhat from those of Colonel Gorgas, who thinks* that the future of the white race lies principally in the tropics. The general opinion among Americans on the Isthmus seems to be that, as far as they are concerned, they would, if engaged in the tropical parts of South or Central America, avail themselves of the improving means of

* "Sanitation in the Canal Zone," by Colonel W. C. Gorgas, M.D. *Journ. Am. Med. Assoc.*, July 6, 1907, vol. 49.

transit to revisit frequently the United States, and would rely upon such vacations in higher latitudes for the retention of their native vigour.

ON THE SHORTENING OF DISTANCES.

The sole object of a ship canal is to shorten sea distance. The following figures are actual steaming distances as calculated by the United States Hydrographic Bureau. From New York to Panama, or any port on the Pacific coast of America north thereof, a reduction of 8400 miles. From New York to ports on the American-Pacific coast south of Panama a reduction varying from 8400 to about 1000 miles, on an average about 5000 miles. The corresponding reduction from Liverpool to these coasts is 6000 and about 2600 respectively. The figures for Antwerp are about the same. From New York to Yokohama, *via* San Francisco, the reduction is 3729 miles, bringing the Japanese port 1805 miles nearer to New York than to Liverpool. From New York to Shanghai the reduction is 1629 miles, which leaves Liverpool 295 miles nearer to Shanghai.

The Panama canal will not shorten the distance between New York and Hong Kong, Suez being still the shorter route, and even to Manila the reduction *via* Panama is only 16 miles; moreover, this small reduction is by way of San Francisco and Yokohama. The all-American route from New York to Manila *via* Panama, Honolulu, and Guam is 128 miles longer than that *via* Suez. As we go further south in the Pacific, however, the Panama route again is the shorter from New York. Thus the distance to Sydney is shortened by 3806 miles (*via* Tahiti), the distance being 2382 less than that between Liverpool and Sydney *via* Colombo, Adelaide, and Melbourne. The reduction between New York and Wellington, N.Z., will be 2542 miles, bringing Wellington 2759 miles nearer to New York than to Liverpool.*

The distance between Liverpool and Wellington *via* the canal is slightly less than that by the Straits of Magellan. There is also a reduction of distance between Liverpool and the northern parts of the Siberian coast. Otherwise the Panama canal does not shorten distances between European ports and those on the "Oriental" side of the Pacific, the route having been short-circuited by the construction of the Suez canal.

New Orleans and other ports on the Mexican gulf obtain even greater reduction of sea distance to Pacific ports than that obtained by New York; and the important island of Jamaica, with its spacious harbour of Kingston, will be placed in a position of centrality for world commerce which it does not at present enjoy. May the opening of the canal help to restore the fortunes of those who have been afflicted by hurricane and earthquake! That the canal will greatly increase

* *I.e.* Liverpool to Colon, 4720; New York to Colon, 1961; difference 2759 miles, the subsequent routes being the same.

the importance of Jamaica as a member of the British Empire there can be no doubt.

We have seen that the greatest reductions of distance resulting from the canal are those between the two coasts of North America. The sea route, however, remains much longer than that by railway, so that the commercial benefit is (relatively to reduction of distance) less than in the opening up of the Pacific coasts of South America, New Zealand, Japan, and the northern parts of Asia. The approximation of the two coasts will, however, have a profound effect upon the naval position of the United States.

Finally, we must note the peculiar position of that part of the world lying between 40° N. and 40° S., and the meridians of 120° E. and 160° E. of Greenwich. This band, which includes Japan, Korea, Shanghai, the Philippines, New Guinea, and most of Australia, is peculiarly situated with respect to canal routes to the manufacturing countries of the Occident.

Near its western margin the Suez and Panama routes to New York are of equal length. Near its eastern margin, which lies, however, mostly at sea, the Suez and Panama routes to Liverpool are of equal length.

On a line rather west of the centre all places are equidistant from New York and Liverpool, the former *viâ* Panama, the latter *viâ* Suez.

ON THE STEAMSHIPS AVAILABLE FOR CANAL TRANSIT.

The Isthmian Canal Commission in the report of 1899 distinguishes between the commercial and the industrial benefits of the canal, meaning by the former term the increased carrying of goods, and by the latter the development of production induced by improved facilities of carriage.

The tables of distances already given show the *potential* commercial advantages, and how they are distributed in different measure among different countries, and these figures have all the permanence which makes geographical figures of such importance. But the actual commercial advantage of a ship canal depends equally upon a second factor, viz. the available ship tonnage. Supposing a Panama canal to be open at the present time, there would be hardly any United States ships to use it, except in transport between home ports from which ships flying foreign flags are debarred. The transport to South America, New Zealand, Australia, Northern China, and Japan would necessarily be almost wholly carried on by ships of other nations, especially British and German.

In the spring of 1908 there was not one steamship flying the flag of the United States between her ports and those of Brazil, the Argentine, Chile, or Peru.*

* *Congressional Record*, February 24, 1908.

The three steamships of the Oceanic Line, formerly plying to Australia, were then laid up in the harbour of San Francisco, being unable, although subsidized for mails by the United States Government, to compete with foreign vessels. There were, however, three United States steamers plying from Puget sound to Japan and China, occasionally reaching the Philippines.

The mails from New York and the other Atlantic ports of the United States to Brazil and the Argentine go *viâ* Europe, so that in this important matter New York is actually 3000 miles further than Europe, instead of being 370 miles nearer, to those countries.*

Ships receiving the United States mail subsidy, the only form of subsidy given, have to be American built, manned by Americans, and the diet of the sailors is prescribed by law. Senator Depew † says that, "The labor unions have rightly and properly taken care of their wages. The result is that the cost in wages and food to run American ships under American conditions across the Pacific is double that of European or Japanese steamers."

The relative cost of operating American and European vessels was given by the Hon. Elihu Root, Secretary of State, in an address delivered November 30, 1906, ‡ as follows:—

The operation of an American steamship of 2500 tons costs \$18,289 per annum more than that of a British ship of this tonnage, or \$7·31 more per ton; and

The operation of an American steamship of 3500 tons costs \$15,315 per annum more than that of a German ship of the same size, or \$4·37 more per ton.

Thus it is evident that in spite of geographical advantages, there is at present some ground for the extreme opinion sometimes expressed in the United States, that the canal is being built with American money for the use of Europe—and, one may add, of Japan.

What attempts may be made to remedy this state of things, and what effects such attempts may have, are speculative matters which do not come within the scope of this paper.

THE COST OF THE CANAL.

Of the existing canals for ocean-going ships that of Suez was built by a company as a commercial undertaking, to earn dividends from tolls. It cost \$90,000,000. The Manchester ship canal is partly commercial, partly industrial, *i.e.* the large contribution of the city of Manchester was made, not as a financial speculation, but in order

* Senator Gallinger, *loc. cit.*

† *Loc. cit.*

‡ Address to Mississippi Commercial Congress, Kansas City, revised by Mr. Root, and published *Nat. Geogr. Mag.*, 1907, vol. 18, pp. 61–72.

to promote an undertaking likely to develop the industries of the city. This canal, partly commercial, partly industrial, cost \$75,000,000. The Kiel canal has further a military purpose, providing a short line of communication for warships. It cost \$40,000,000. The Panama canal is commercial, industrial, and military, and will cost more than all the above put together.

Up to June 30, 1908, the United States Government have spent \$126,047,062 on the Panama canal,* made up as follows :—

Payment to New Panama Canal Company, \$40,000,000, and	
to Republic of Panama, \$10,000,000	 \$50,000,000
Expenditure on work prior to July 1, 1907	 43,172,408
Expenditure on work, July 1, 1907—June 30, 1908	 32,874,654
	<hr/>
	\$126,047,062

The amount authorized to be appropriated by the Act of June 28, 1902, was \$135,000,000 plus \$50,000,000 purchase money = \$185,000,000 in all, for the “canal, harbours, and defences.” What the total cost will be is unknown, but Colonel Goethals stated in evidence (January, 1908) that the canal would cost at least \$250,000,000, and possibly as much as \$500,000,000. The combined cost of the Suez, Manchester, and Kiel canals has been \$205,000,000.

The following important ship canals have been completed for smaller sums :—

U.S., S.St. Marie (somewhat more than)	 \$6,000,000
Canadian do. (nearly)	 4,000,000
Amsterdam	 10,000,000
Corinth (about)	 5,000,000
Cronstadt (about)	 10,000,000
Welland (Lake Erie—Lake Ontario)	 24,000,000
	<hr/>
	\$59,000,000

Adding these figures to those already given, we have a grand total of \$264,000,000 for the cost of nine of the greatest existing ship canals, which is about the same as the lowest current official estimate for the final cost of the Panama canal.

In my study of the Panama canal, of which the present paper is necessarily but a summary account, I have been assisted by many persons, and desire to thank particularly the Department of State at Washington, the Rt. Hon. James Bryce, the Rt. Hon. Lord Avebury, Mr. Claude Mallet, C.M.G., and Colonel G. E. Church. Also Colonel Goethals, chairman of the Isthmian Canal Commission, and his colleagues and assistants, who received me most kindly. Among them I must particularly thank Colonel Gorgas, Major Gaillard, Major Sibert, Major Harding, Mr. Jackson Smith, Mr. Bucklin Bishop, Mr. Arango, Mr. G. R. Shanton, Mr. William Gerig, and Mr. Mason W. Mitchell. I also

* *Canal Record*, August 12, 1908.

profited by the learning of Mr. Tracy Robinson, an historian of Isthmian affairs.

I left the society of the men who are making the canal with great regret. I cherish the hope that I may revisit them, that I may see their task crowned with success, and that I may yet gaze from the deck of an ocean liner upon the terraced sides of Culebra cut.

Before the paper, the PRESIDENT: No words are needed on my part to introduce to you Dr. Vaughan Cornish, who has given us so many papers before, and whose lectures we have so often enjoyed. He has generally for his study taken the study of waves, but to-night he deals with a different class of problems. He is going to discuss the Panama canal, and discuss it from every possible point of view which can in any way be considered geographical. As you have come to listen to the lecture and not to me, I will, without more ado, ask Dr. Cornish to kindly deliver his lecture.

After the paper, Colonel G. E. CHURCH: We have listened with keen interest to the lecturer. He thoroughly understands that any one describing the work being carried out at Panama should be extremely careful of his statements. I do not share in the idea that the white man can compete with other races in occupying tropical lands. There are, of course, in America immense areas of these, notably in the Amazon valley, mostly malaria infested; but I do not believe that the mosquito is entirely to blame for the malaria. I have in mind at this moment a work which is being carried out in the Amazon valley, an old enterprise of mine, the Madeira and Mamoré railway, situated exactly in the same latitude south of the equator as Panama is to the north. There are now 1500 men employed on that work, and measures of sanitation have not been taken similar to those of Panama, although every provision has been made for the health of the men. I have recently had information from there that the negro, while he does not fall ill with malaria so quickly as the white man, recuperates from it with less rapidity. It is a curious fact that there are no mosquitoes but plenty of malaria along the line of the falls of the Madeira. I have no doubt that the white man could occupy the whole Amazon valley if he had the United States Treasury behind him to give sanitation like that of Panama. Unfortunately, the emigrant to new countries is generally very poor, and is unable to carry with him many tons of petroleum, and organize brigades of men to fight mosquitoes. These lands cannot be occupied by white men in competition with negroes and other races of tropical breed. I have been struck with the marvellous feats of administrative ability performed at Panama by the French and Americans, and yield humble tribute to the engineering talent of France and to that of the corps of engineers of the United States army, that they should have planned and carried out so admirably such magnificent works as are now proceeding there. But I also submit that they have not yet tackled the great problems incident to the cutting of the canal; these are still to come, and we must withhold our judgment until we see them well under way. It is now twenty-seven years since work was commenced by the French, and it is an *astounding fact that the definitive plans for the canal have not yet been decided upon*. Meanwhile, millions sterling have been poured into that Danaïdes sieve simply to "*make the dirt fly*."

But what is the Panama canal being cut for? Is it for commercial purposes? or strategic reasons? or for a better control of the Pacific ocean? Look for a moment at its commercial position. Ninety-four per cent. of the population of the

PROFILE OF GATUN DAM BORINGS

THE PANAMA CANAL. CORNISH.

THE GEOGRAPHICAL JOURNAL 1909.

PROFILE OF GATUN DAM BORING

Diversion Channel

Indurated Clay

Horizontal Scale 10000
Vertical Scale 2000

THE PANAMA CANAL
from the report of the
ISTHMIAN CANAL COMMISSION
illustrating a
VAUGHAN CORRECTION

Nat. Scale 1: 200,000 or 1 In.

Dams

THE PANAMA CANAL

from the reports of the
ISTHMIAN CANAL COMMISSION
illustrating a paper by
VAUGHAN CORNISH, D.Sc.

SECTION OF GATUN DAM. Horizontal & Vertical Scale 8000

Nat. Scale 1: 200,000 or 1 Inch = 3.156 Stat. Miles.

Dams

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