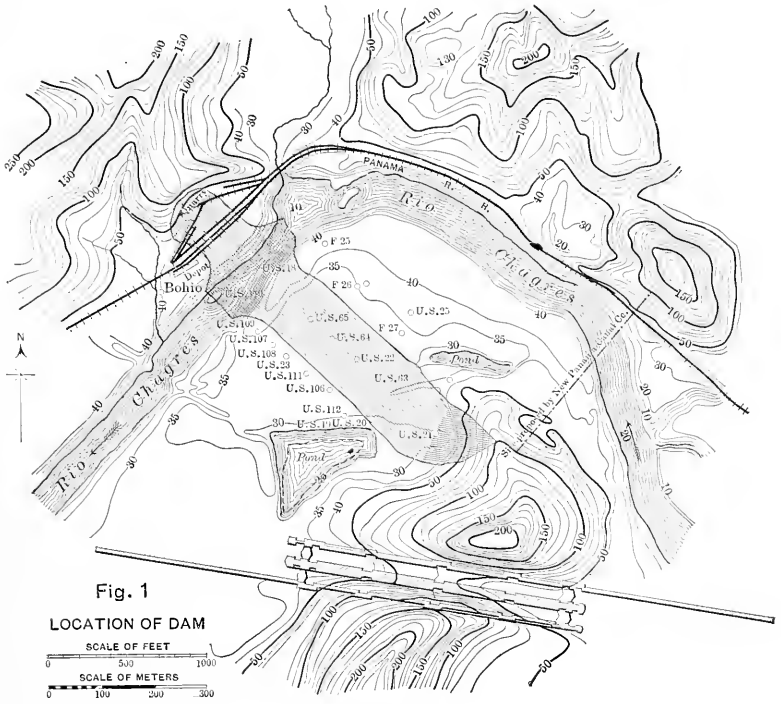
for a length of 800 feet for the purpose of a turning-basin. This brings the line into the canal proper, forming a well-protected harbor for nearly a mile inside of the shore line. The distance from the 6-fathom line to this interior harbor is about 2 miles. The total cost of constructing the channel into the harbor and the harbor itself is $8,057,707, and the annual cost of maintenance is placed at $30,000. The harbor would be perfectly protected from the northers which occasionally blow with such intensity in the Bay of Limon, and it could readily be made in all weathers by vessels seeking it.

370. Panama Harbor and Entrance to Canal.—The harbor at the Pacific end of the channel where it joins Panama Bay is of an entirely different character in some respects. The Bay of Panama is a place of light winds. Indeed it has been asserted that the difficulties sometimes experienced by sailing-vessels in finding wind enough to take them out of Panama Bay are so serious as to constitute a material objection to the location for a ship-canal on the Panama route. This difficulty undoubtedly exists at times, but the simple fact is to be remembered that Panama was a port for sailing-ships for more than two hundred years before a steamship was known. The harbor of Panama, as it now exists, is a large area of water at the extreme northern limit of the bay, immediately adjacent to the city of Panama, protected from the south by the three islands of Perico, Naos, and Culebra. It has been called a roadstead. There is good anchorage for heavy-draft ships, but for the most part the water is shallow. With the commission's requirement of a minimum depth of water of 35 feet, a channel about 4 miles long from the mouth of the Rio Grande to the 6-fathom line in Panama Bay must be excavated. This channel would have a bottom width of 200 feet with side slopes of 1 on 3 where the material is soft. Considerable rock would have to be excavated in this channel. At 4.41 miles from the 6-fathom line is located a wharf at the point called La Boca. A branch of the Panama Railroad Company runs to this wharf, and at the present time deep-draft ships lie up alongside of it to take on and discharge cargo. The wharf is a steel frame structure, founded upon steel cylinders, carried down to bed-rock by the pneumatic process. Its cost was about $1,284,000. The

total cost of the excavated channel leading from Panama harbor to the pier at La Boca is estimated by the commission at $1,464,-



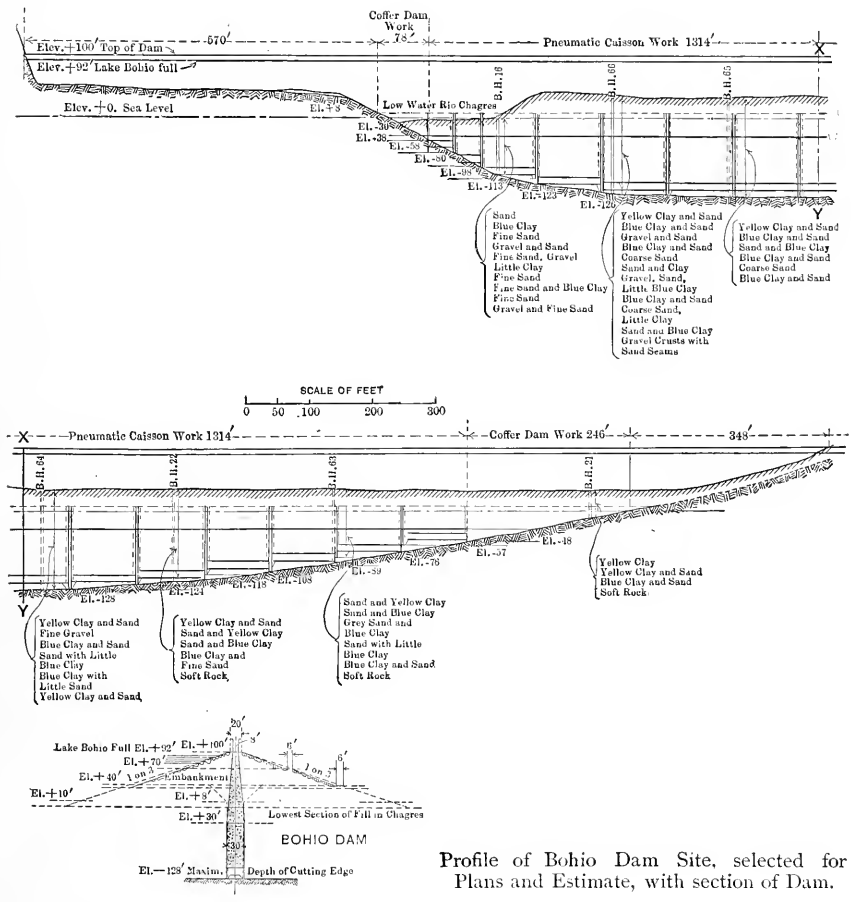
The Bohio Dam Site.

513. As the harbor at Panama is considered an open roadstead, it requires no estimate for annual cost of maintenance.

371. The Route from Colon to Bohio.—Starting from the harbor of Colon, the prism of the canal is excavated through the low and for the most part marshy ground to the little village called Bohio. The prism would cut the Chagres River at a number of points, and would require a diversion-channel for that river for a distance of about 5 miles on the westerly side of the canal. Levees, or protective embankments, would also be required on the same side of the canal between Bohio and Gatun, the Chagres River leaving the canal line at the latter point on its way to the sea.

372. The Bohio Dam.—The principal engineering feature of the entire route is found at Bohio; it is the great dam across the Chagres River at that point, forming Lake Bohio, the summit level of the canal. The new Panama Canal Company located this dam at a point about 17 miles from Colon, and designed to make it an earth structure suitably paved on its faces, but without any other masonry feature. Some borings had been made along the site, and test-pits were also dug by the French engineers. It was the conviction of the Isthmian Canal Commission, however, that the character of the proposed dam might be affected by a further examination of the subsurface material at the site. Consequently the boring parties of the Commission sunk a large number of bore-holes at six different sections or possible sites along the river in the vicinity of the French location. These borings revealed great irregularity in the character and disposition of the material below the bed and banks of the river. In some places the upper stratum of material was almost clear clay, and in other places clear sand, while all degrees of admixture of clay and sand were also found. At the French site the bed-rock at the deepest point is 143 feet below sea-level, with large masses of pervious and semi-pervious sand, gravel, and mixtures of those materials with clay. Apparently there is a geological valley in the rock along the general course of the Chagres River in this vicinity filled with sand, gravel, and clay, irregularly distributed and with all degrees of admixture, large masses in all cases being of open texture and pervious to water. The site adopted by the commission for the purposes of its plans and estimates is located nearly half a mile down the course of the river from that selected by the new Panama Canal Company. The geological valley is nearly 2000 feet wide at this location, but the deepest rock disclosed by the borings of the commission is but 128 feet below sea-level. The actual channel of the river is not more than 150 feet wide and lies on the extreme easterly side of the valley. The easterly or right bank of the river at this place is clean rock and rises abruptly to an elevation of about 40 feet above the river surface at ordinary stages. The left or westerly bank of the river is compacted clay and sand, and rises equally as abruptly as the rocky bank of the other side, and to about the

same elevation. From the top of the abrupt sandy clay bank a plateau of rather remarkable uniformity of elevation extends for about 1200 feet in a southwesterly direction to the rocky hill in which the Bohio locks would be located. The rock slope on the easterly or northerly bank of the river runs down under the sandy river-bed, but at such an inclination that within the limits of the channel the deepest rock is less than 100 feet below sea-level.



Profile of Bohio Dam Site, selected for Plans and Estimate, with section of Dam.

After the completion of all its examinations and after a careful study of the data disclosed by them, the commission deemed

it advisable to plan such a dam as would cut off absolutely all possible subsurface flow or seepage through the sand and gravel below the river surface. It is to be observed tha such a subsurface flow might either disturb the stability of an earth dam or endanger the water-supply of the summit level of the canal or both. The plan of dam finally adopted by the commission for the purposes of its estimates is shown by the accompanying plans and sections. A heavy core-wall of concrete masonry extends from bed-rock across the entire geological valley to the top of the structure, or to an elevation of 100 feet above sea-level, thus absolutely closing the entire valley against any possible flow. The thickness of this wall at the bottom is 30 feet, but at an elevation of 30 feet below sea-level its sides begin to batter at such a rate as to make the thickness of the wall 8 feet at its top. On either side of this wall are heavy masses of earth embankment of selected material properly deposited in layers with surface slopes of 1 on 3. As shown by the plans, the lower portions of the core-wall of this dam would be sunk to bed-rock by the pneumatic process, the joints between the caissons being closed and sealed by cylinders sunk in recesses or wells, also as shown by the plans.

373. Variation in Surface Elevation of Lake.—The profile of this route shows that the summit level would have an ordinary elevation of 85 feet above the sea, but it may be drawn down for uses of the canal to a minimum elevation of 82 feet above the same datum. On the other hand, under circumstances to be discussed later, it may rise during the floods of the Chagres to an elevation of 90 or possibly 91 or 92 feet above the level of the sea. The top of the dam therefore would be from 8 to 10 feet above the highest possible water surface in the lake, which is sufficient to guard against wash or overtopping of the dam by waves. The total width of the dam at its top would be 20 feet, and the entire inner slope would be paved with heavy riprap suitably placed and bedded.

374. Extent of Lake Bohio and the Canal Line in It.—This dam would create an artificial lake having a superficial area during high water of about 40 square miles. The water would be backed up to a point called Alhajuela, about 25 miles up the river

from Bohio. For a distance of nearly 14 miles, i.e., from Bohio to Obispo, the route of the canal would lie in this lake. Although the water would be from 80 to 90 feet deep at the dam for several miles below Obispo, it would be necessary to make some excavation along the general course of the Chagres in order to secure the minimum depth of 35 feet for the navigable channel.

375. The Floods of the Chagres.—The feature of Lake Bohio of the greatest importance to the safe and convenient operation of the canal is that by which the floods of the river Chagres are controlled or regulated. That river is but little less than 150 miles long, and its drainage area as nearly as can be estimated,

Location of the Proposed Alhajuela Dam on the Upper Chagres.

contains about 875 square miles. Above Bohio its current moves some sand and a little silt in times of flood, but usually it is a clear-water stream. In low water its discharge may fall to 350 cubic feet per second.

As is well known, the floods of the Chagres have at times been regarded as almost if not quite insurmountable obstacles to the construction of a canal on this line. The greatest flood of which there is any semblance of a reliable record is one which occurred in 1879. No direct measurements were made, but it is stated with apparent authority that the flood elevation at Bohio was 39.3 feet above low water. If the total channel through which the flood flowed at that time had been as large as at present, actual gaugings or measurements of subsequent floods show that the maximum discharge in 1879 might have been at the rate of 136,000 cubic feet per second. As a matter of fact the total channel section in that year was less than it is at the present time. Hence if it be assumed that a flood of 140,000 cubic feet per second mus be controlled, an error on the safe side will be committed. Other great floods of which there are reliable records are as follows:

1885	Height	at	Bohio	33.8	feet	above	low	water.
1888:	"	"	"	34.7	"	"	"	"
1890:	"	"	"	32.1	"	"	"	"
1893:	"	"	"	28.5	"	"	"	"

The maximum measured rate of the 1890 flood was 74,998 cubic feet per second, and that of 1893, 48,975 cubic feet per second. It is clear, therefore, that a flood flow of 75,000 cubic feet per second is very rare, and that a flood of 140,000 cubic feet per second exceeds that of which we have any record for practically forty years.

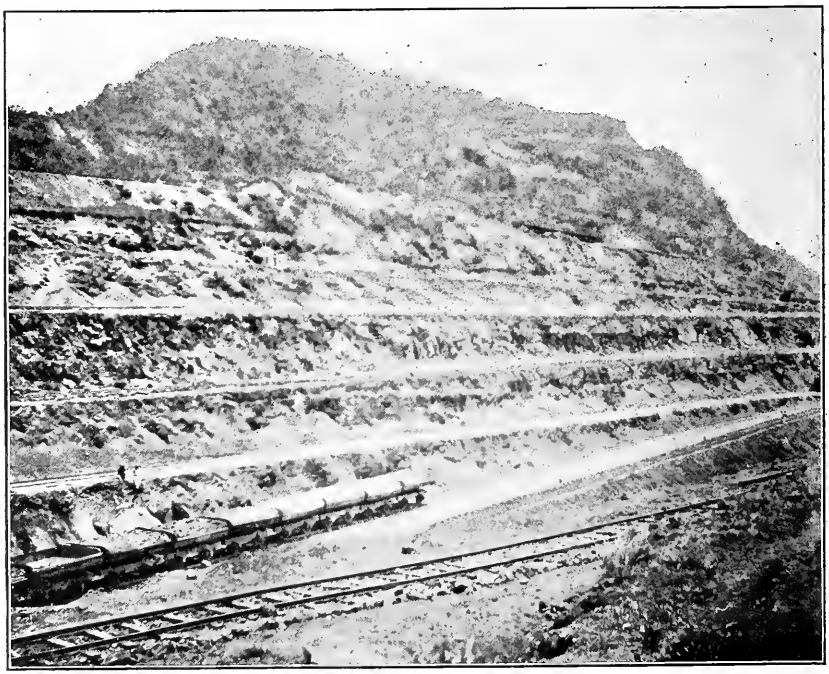
376. The Gigante Spillway or Wasteweir.—It is obvious that the dam, as designed by the commission, is of such character that no water must be permitted to flow over its crest, or even in immediate proximity to the down-stream embankment. Indeed it is not intended by the commission that there shall be any waste-way or discharge anywhere near the dam. At a point about 3 miles southwest of the site of the dam at Bohio is a low saddle or notch in the hills near the head-waters of a small stream called the Gigante River. The elevation of this saddle or notch is such that a solid masonry weir with a crest 2000 feet long may readily

be constructed with its foundations on bed-rock without deep excavation. This structure is called the Gigante spillway, and all surplus flood-waters from the Chagres would flow over it. The waters discharged would flow down to and through some large marshes, one called Peña Blanca and another Agua Clara, before rejoining the Chagres. Inasmuch as the canal line runs just easterly of those marshes, it would be necessary to protect it with the levees or embankments to which allusion has already been made. These embankments are neither much extended nor very costly for such a project. The protection of the canal would be further aided by a short artificial channel between the two marshes, Pñea Blanca and Agua Clara, for which provision is made in the estimates of the commission. After the surplus waters from the Gigante spillway pass these marshes they again enter the Chagres River or flow over the low, half-submerged country along its borders, and thence through its mouth to the sea near the town of Chagres, about 6 miles northwest of Gatun.

377. Storage in Lake Bohio for Driest Dry Season.—The masonry crest of the Gigante spillway would be placed at an elevation of 85 feet above the sea, identically the same as that which may be called the normal summit level of the canal. It is estimated that the total uses of water in the canal added to the loss by evaporation, taken at six inches in depth per month, from the surface of the lake will amount to about 1070 cubic feet per second if the traffic through the canal should amount to 10,000,000 tons per annum in ships of ordinary size. This draft per second is the sum of 406 cubic feet per second for lockage, 207 for evaporation, 250 for leakage at lock-gates, and 200 for power and other purposes, making a total of 1063, which has been taken as 1070 cubic feet per second. The amount of storage in Lake Bohio between the elevations of 85 and 82 feet above sea-level, as designed, is sufficient to supply the needs of that traffic in excess of the smallest recorded low-water flow of the Chagres River during the dry season of a low-rainfall year. The lowest monthly average flow of the Chagres on record at Bohio is 600 cubic feet per second for March, 1891, and for the purposes of this computation that minimum flow has been supposed to continue for three months. This includes a sensible margin of safety. In not

even the driest year, therefore, can it be reasonably expected that the summit level of the canal would fall below the elevation of 82 feet until the total traffic of the canal carried in ships of the present ordinary size shall exceed 10,000,000 tons. If the average size of ships continues to increase, as will probably be the case, less water in proportion to tonnage will be required for the purposes of lockage. This follows from the fact that with a given tonnage the greater the capacity of the ships the less the number required, and consequently the less will be the number of lockages made.

378. Lake Bohio as a Flood-controller.—On the other hand it can be shown that with a depth of 5 feet of water on the crest of the Gigante spillway the discharge of that weir 2000 feet long



The Eastern Face of the Culebra Cut.

will be at the rate of 78,260 cubic feet per second. If the flood-waters of the Chagres should flow into Lake Bohio until the head of water on the crest of the Gigante weir rises to $7\frac{1}{2}$ feet, the rate

of discharge over that weir would be 140,000 cubic feet per second, which, as already shown, exceeds at least by a little the highest flood-rate on record. The operation of Lake Bohio as a flood controller or regulator is therefore exceedingly simple. The flood-waters of the Chagres would pour into the lake and immediately begin to flow over the Gigante weir, and continue to do so at an increasing rate as the flood continues. The discharge of the weir is augmented by the increasing flood, and decreases only after the passage of the crest of the flood-wave. No flood even as great as the greatest supposable flood on record can increase the elevation of the lake more than 92 to 92½ feet above sea-level, and it will only be at long intervals of time when floods will raise that elevation more than about 90 feet above sea-level. The control is automatic and unfailingly certain. It prevents absolutely any damage from the highest supposable floods of the Chagres, and reserves in Lake Bohio all that is required for the purposes of the canal and for wastage by evaporation through the lowest rainfall season. The floods of the Chagres, therefore, instead of constituting the obstacle to construction and convenient maintenance of the canal heretofore supposed, are deprived of all their prejudicial effects and transformed into beneficial agents for the operation of the waterway.

379. Effect of Highest Floods on Current in Channel in Lake Bohio.—The highest floods are of short duration, and it can be stated as a general law that the higher the flood the shorter its duration. The great floods which it is necessary to consider in connection with the maintenance and operation of this canal would last but a comparatively few hours only. The great flood-flow of 140,000 cubic feet per second would increase the current in the narrowest part of the canal below Obispo to possibly 5 feet per second for a few hours only, but that is the only inconvenience which would result from such a flood-discharge. That velocity could be reduced by additional excavation.

380. Alhajuela Reservoir not Needed at Opening of Canal.—Inasmuch as this system of control, devised and adopted by the Isthmian Canal Commission, is completely effective in regulating the Chagres floods; the reservoir proposed to be constructed by the new Panama Canal Company at Alhajuela on the Chagres

about 11 miles above Obispo is not required, and the cost of its construction would be avoided. It could, however, as a project be held in reserve. If the traffic of the canal should increase to such an extent that more water would be needed for feeding the summit level, the dam could be built at Alhajuela so as to impound enough additional water to accommodate, with that stored in Lake Bohio, at least five times the 10,000,000 annual traffic already considered. Its existence would at the same time act with substantial effect in controlling the Chagres floods and relieve the Gigante spillway of a corresponding amount of duty.

381. Locks on Panama Route.—The locks on the Panama route are designed to have the same dimensions as those in Nicaragua, as was stated in the lecture on that route. The usable length is 740 feet and the clear width 84 feet. They would be built chiefly of concrete masonry, while the gates would be of steel and of the mitre type.

382. The Bohio Locks.—The great dam at Bohio raises the water surface in the canal from sea-level in the Atlantic maritime section to an ordinary maximum of 90 feet above sea-level; in other words, the maximum ordinary total lift would be 90 feet. This total lift is divided into two parts of 45 feet each. There is therefore a flight of two locks at Bohio; indeed there are two flights side by side, as the twin arrangement is designed to be used at all lock sites on both routes. The typical dimensions and arrangements of these locks, with the requisite culverts and other features, are shown in the plans and sections between pages 396 and 397, Part V. They are not essentially different from other great modern ship-canal locks. The excavation for the Bohio locks is made in a rocky hill against which the south-westerly end of the proposed Bohio dam rests, and they are less than 1000 feet from it.

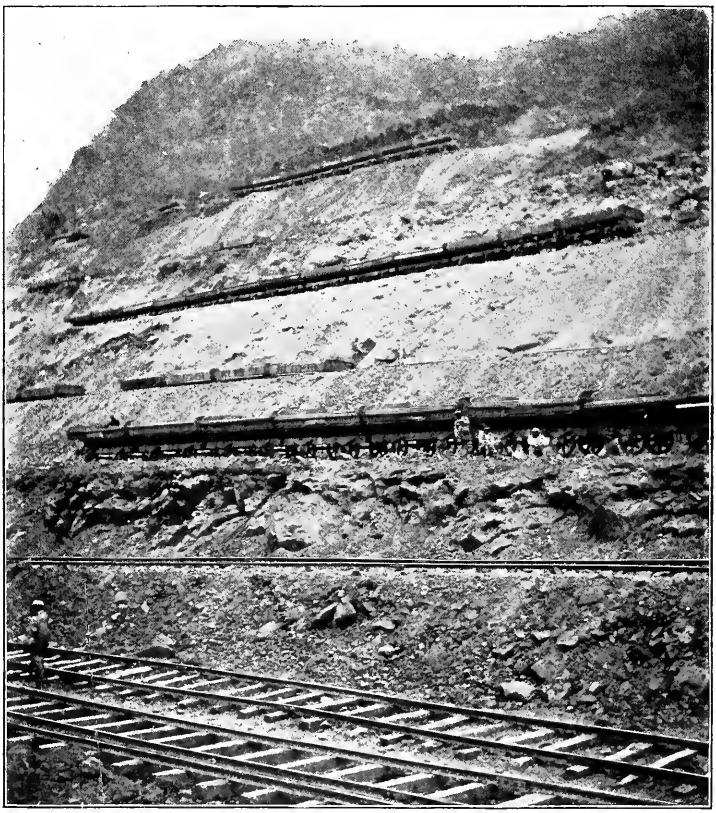
383. The Pedro Miguel and Miraflores Locks.—After leaving Bohio Lake at Obispo a flight of two locks is found at Pedro Miguel, about 7.9 miles from the former or $21\frac{1}{2}$ miles from Bohio. These locks have a total ordinary maximum lift of 60 feet, divided into two lifts of 30 feet each. The fifth and last lock on the route is at Miraflores. The average elevation of water between Pedro Miguel and Miraflores is 30 feet above mean sea-level. Inas-

much as the range of tide between high and low in Panama Bay is about 20 feet, the maximum lift at Miraflores is 40 feet and the minimum about 20. The twin locks at Miraflores bring the canal surface down to the Pacific Ocean level, the distance from those locks to the 6-fathom curve in Panama Bay being 8.54 miles. There are therefore five locks on the Panama route, all arranged on the twin plan, and, as on the Nicaragua route, all are founded on rock.

384. Guard-gates near Obispo.— Near Obispo a pair of guard-gates are arranged "so that if it should become necessary to draw off the water from the summit cut the level of Lake Bohio would not be affected."

385. Character and Stability of the Culebra Cut.—An unprecedented concentration of heavy cutting is found between Obispo and Pedro Miguel. This is practically one cut, although the northwesterly end toward Obispo is called the Emperador, while the deepest part at the other end, about 3 miles from Pedro Miguel, is the great Culebra cut with a maximum depth on the centre line of the canal of 286 ft. On page 93 of the Isthmian Canal Commission's report is the following reference to the material in this cut: "There is a little very hard rock at the eastern end of this section, and the western 2 miles are in ordinary materials. The remainder consists of a hard indurated clay, with some softer material at the top and some strata and dikes of hard rock. In fixing the price it has been rated as soft rock, but it must be given sl pes equivalent to those in earth. This cut has been estimated on the basis of a bottom width of 150 feet, with side slopes of 1 on 1.' When the old Panama Canal Company began its excavation in this cut considerable difficulty was experienced by the slipping of the material outside of the limits of the cut into the excavation, and the marks of that action can be seen plainly at the present time. This experience has given an impression that much of the material in this cut is unstable, but that impression is erroneous. The clay which slipped in the early days of the work was not drained, and like wet clay in numerous places in this country it slipped down into the excavation. This material is now drained and is perfectly stable. There is no reason to anticipate any future difficulty if reasonable

conditions of drainage are maintained. The high faces of the cut will probably weather to some extent, although experience with such clay faces on the isthmus indicates that the amount of



The Culebra Cut.

such action will be small. As a matter of fact the material in which the Culebra cut is made is stable and will give no sensible difficulty in maintenance.

386. Small Diversion-channels.—Throughout the most of the distance between Colon and Bohio on the easterly side of the canal the French plan contemplated an excavated channel to receive a portion of the waters of the Chagres as well as the flow of two smaller rivers, the Gatuncillo and the Mindi, so as to con-

duct them into the Bay of Manzanillo, immediately to the east of Colon. That so-called diversion-channel was nearly completed. Under the plan of the commission it would receive none of the Chagres flow, but it would be available for intercepting the drainage of the high ground easterly of the canal line and the flow of the two small rivers named, so that these waters would not find their way into the canal. There are a few other small works of similar character in different portions of the line, all of which were recognized and provided for by the commission.

387. Length and Curvature.—The total length of the Panama route from the 6-fathom curve at Colon to the same curve in Panama Bay is 49.09 miles. The general direction of the route in passing from Colon to Panama is from northwest to southeast, the latter point being about 22 miles east of he Atlantic terminus. The depression through which the line is laid is one of easy topography except at the continental divide in the Culebra cut. As a consequence there is little heavy work of excavation, as such matters go except in that cut. A further consequence of such topography is a comparatively easy alignment, that is, one in which the amount of curvature is not high. The smallest radius of curvature is 3281 feet at the entrace to the inner harbor at the Colon end of the route, and where the width is 800 feet. The radii of the remaining curves range from 6234 feet to 19,629 feet.

The following table gives all the elements of curvature on the route and indicates that it is not excessive:

Number of Curves.	Length.	Radius.	Total Curvature.
	Miles	Feet.	° ′
1	0.88	19,629	14 17
1	.48	13,123	11 04
4	4.22	11,483	111 32
15	11.61	9,842	355 50
4	2.44	8,202	90 20
2	1.67	6,562	77 00
1	.73	6,234	35 45
1	.82	3,281	75 51
	22.85		771 39

388. Principal Items of Work to be Performed.—The principal items of the total amount of work to be performed in completing

the Panama Canal, under the plan of the commission, can be classified as shown in the following table:

Dredging	27,659,540	cu. yds.
Dry earth	14,386,954	"
Soft rock	39,893,235	"
Hard rock	8,806,340	"
Rock under water	4,891,667	"
Embankment and back-filling	1,802,753	"
Total	97,440,489	"
Concrete	3,762,175	cu. yds.
Granite	13,820	"
Iron and steel	65,248,900	lbs.
Excavation in coffer-dam	7,260	cu. yds.
Pneumatic work	108,410	"

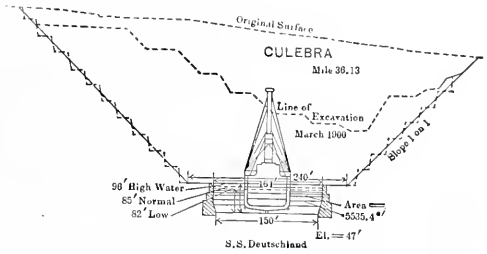
389. Lengths of Sections and Elements of Total Cost. — The lengths of the various sections of this route and the costs of completing the work upon them are fully set forth in the following table, taken from the commission's report, as were the two preceding:

TOTAL ESTIMATED COST.

	Miles.	Cost.
Colon entrance and harbor	2.39	$8,057,707
Harbor to Bohio locks, including levees	14.42	11,099,839
Bohio locks, including excavation	.35	11,567,275
Lake Bohio	13.61	2,952,154
Obispo gates	.....	295,434
Culebra section	7.91	44,414,460
Pedro Miguel locks, including excavation and dam	.35	9,081,321
Pedro Miguel level	1.33	1,192,286
Miraflores locks, including excavation and spillway	.20	5,781,401
Pacific level	8.53	12,427,971
Bohio dam	.....	6,369,640
Gigante spillway	.....	1,209,419
Peña Blanca outlet	.....	2,448,076
Chagres diversion	.....	1,929,982
Gatun diversion	.....	100,000
Panama Railroad diversion	.....	1,267,500
Total	49.09	120,194,465
Engineering, police, sanitation, and general contingencies, 20 per cent.	.....	24,038,893
Aggregate	.....	$144,233,358

The item in this table called Panama Railroad diversion affords provision for the reconstruction of the railroad necessitated by

the formation of Lake Bohio. That lake would submerge the present location of the railroad for 14 or 15 miles.



The Culebra Cut with Steamer Deutschland in it.

390. The Twenty Per Cent Allowances for Exigencies.—It will be observed that in the estimates of cost of the canal on both the Nicaragua and the Panama routes, 20 per cent is allowed for "engineering, police, sanitation, and general contingencies." For the purposes of comparison the same percentage to cover these items was used on both routes. As a matter of fact the large amount of work which has already been performed on the Panama route removes many uncertainties as to the character of material and other features of difficulty which would be disclosed only after the beginning of the work in Nicaragua. It has therefore been contended with considerable basis of reason that a less percentage to cover these uncertainties should be employed in connection with the Panama estimates than in connection with those for the Nicaragua route. Indeed it might be maintained that the exigencies which increase cost should be made proportional to the length of route and the untried features. On the other hand, both Panama and Colon are comparatively large centres of population, and, furthermore, there is a considerable population stretched along the line of the Panama Railroad between those points. The climate and the unsanitary condition of practically every centre of population in Central America and on the isthmus contribute to the continual presence of tropical fevers, and other diseases contingent upon the existing conditions of life. It is probable, among other things, that yellow fever is always present on the isthmus. Inasmuch as the Nicaragua route is practically without population, the amount of

disease existing along it is exceedingly small, there being practically no people to be sick. The initial expenditure for the sanitation of the cities at the extremities of the Panama route, as well as for the country between, would be far greater for that route than on the Nicaragua. This fact compensates, to a substantial extent at least, for the physical uncertainties on the Nicaragua line. Indeed a careful examination of all the conditions existing on both routes indicates the reasonableness of applying the same 20 per cent to both total estimates of cost.

391. Value of Plant, Property, and Rights on the Isthmus.— The preceding estimated cost of $144,233,358 for completing the Panama Canal must be increased by the amount necessary to be paid for all the property and rights of the new Panama Canal Company on the isthmus. A large amount of excavation has been performed, amounting to 77,000,000 cubic yards of all classes of materials, and nearly all the right of way has been purchased. The new Panama Canal Company furnished the commission with a detailed inventory of its entire properties, which the latter classified as follows:

1. Lands not built on.
2. Buildings, 2431 in number, divided among 47 subclassifications.
3. Furniture and stable outfit, with 17 subclassifications.
4. Floating plant and spare parts, with 24 subclassifications.
5. Rolling plant and spare parts, with 17 subclassifications.
6. Plant, stationary and semi-stationary, and spare parts, with 25 subclassifications.
7. Small material and spare parts, with 4 subclassifications.
8. Surgical and medical outfit.
9. Medical stores.
10. Office supplies, stationery.
11. Miscellaneous supplies, with 740 subclassifications.

The commission did not estimate any value for the vast amount of plant along the line of the canal, as its condition in relation to actual use is uncertain, and the most of it would not be available for efficient and economical execution of the work by modern American methods. Again, a considerable amount

of excavated material along some portions of the line has been deposited in spoil-banks immediately adjacent to the excavation from which it was taken, and would have to be rehandled in forming the increased size of prism contemplated in the commission's plan.

In view of all the conditions affecting it, the commission made the following estimate of the value of the property of the new Panama Canal Company, as it is now found on the Panama route:

Canal excavation	$21,020,386
Chagres diversion	178,186
Gatun diversion	1,396,456
Railroad diversion (4 miles)	300,000
	22,895,028
Contingencies, 20 per cent	4,579,005
Aggregate	27,474,033
Panama Railroad stock at par	6,850,000
Maps, drawings, and records	2,000,000
	$36,324,033.

The commission added 10 per cent to this total "to cover omissions, making the total valuation of the" property and rights as now existing, $40,000,000.

In computing the value of the channel excavation in the above tabulation it was estimated that "the total quantity of excavation which will be of value in the new plan is 39,586,332 cubic yards."

392. Offer of New Panama Canal Company to Sell for $40,000,000. —In January, 1902, the new Panama Canal Company offered to sell and transfer to the United States Government all its property and rights on the isthmus of every description for the estimate of the commission, viz., $40,000,000. In order to make a proper comparison between the total costs of constructing the canal on the two routes it is necessary to add this $40,000,000 to the preceding aggregate of $144,233,358, making the total cost of the Panama Canal $184,233,358. It will be remembered that

the corresponding total cost of the Nicaragua Canal would be $189,864,062.

393. Annual Costs of Operation and Maintenance.—It is obvious that the cost of operating and maintaining a ship-canal across the American isthmus would be an annual charge of large

The Railroad Pier at La Boca, the Panama end of the Canal.

amount. A large organized force would be requisite, and no small amount of material and work of various kinds and grades would be needed to maintain the works in suitable condition. The commission made very careful and thorough studies to ascertain as nearly as practicable what these comparative costs would be. In doing this it gave careful consideration to the annual expenditures made in maintaining the various ship-canals of the world, including the Suez, Manchester, Kiel, and St. Mary's

Falls canals. The conclusion reached was that the estimated annual costs of maintenance and operation could reasonably be taken as follows:

For the Nicaragua Canal	$3,300,000
For the Panama Canal	2,000,000
Difference in favor of Panama	$1,300,000

394. Volcanoes and Earthquakes. — Much has been written regarding the comparative liability to damage of canal works along these two routes by volcanic or seismic agencies. As is well known, the entire Central American isthmus is a volcanic region, and in the past a considerable number of destructive volcanic eruptions have taken place at a number of points. There is a line of live volancoes extending southeasterly through Nicaragua and Costa Rica. Many earthquake shocks have occurred throughout Nicaragua, Costa Rica, and the State of Panama, some of which have done more or less damage in large portions of those districts. At the same time many buildings which have been injured have not been substantially built. In fact that has generally been the case. Both routes lie in districts that are doubtless subject to earthquake shocks, but there is little probability that the substantial structures of a canal along either line would be essentially injured by them. The conclusions of the commission as to this feature of the matter are concisely stated in three paragraphs at the top of page 170 of its report:

"It is possible and even probable that the more accurately fitting portions of the canal, such as the lock-gates, may at times be distorted by earthquakes, and some inconvenience may result therefrom. That contingency may be classed with the accidental collision of ships with the gates, and is to be provided for in the same way, by duplicate gates.

"It is possible also that a fissure might open which would drain the canal, and, if it remained open, might destroy it. This possibility should not be erected by the fancy into a threatening danger. If a timorous imagination is to be the guide, no great work can be undertaken anywhere. This risk may be classed

with that of a great conflagration in a city like that of Chicago in 1871, or Boston in 1872.

"It is the opinion of the commission that such danger as exists from earthquakes is essentially the same for both the Nicaragua and Panama routes, and that in neither case is it sufficient to prevent the construction of the canal."

The Nicaragua route crosses the line of live volcanoes running from northwest to southeast through Central America, and the crater of Ometepe in Lake Nicaragua is about 11 miles only from the line. The eruptions of Pelée and Soufrière show that such proximity of possible volcanic action may be a source of great danger, although even the destruction by them does not certainly indicate damage either to navigation or to canal structures at the distance of 11 miles. Whatever volcanic danger may exist lies on the Nicaragua route, for there is no volcano nearer than 175 miles to the Panama route.

395. Hygienic Conditions on the Two Routes.—The relative healthfulness of the two routes has already been touched upon. There is undoubtedly at the present time a vast amount of unhealthfulness on the Panama route, and practically none on the Nicaragua route, but this is accounted for when it is remembered, as has also been stated, that there is practically no population on the Nicaragua route and a comparatively large population along the Panama line. There is a wide-spread, popular impression that the Central American countries are necessarily intensely unhealthful. This is an error, in spite of the facts that the construction of the Panama Railroad was attended with an appalling amount of sickness and loss of life, and that records of many epidemics at other times and in other places exist in nearly all of these countries. There are the best of good reasons to believe that with the enforcement of sanitary regulations, which are now well understood and completely available, the Central American countries would be as healthful as our Southern States. A proper recognition of hygienic conditions of life suitable to a tropical climate would work wonders in Central America in reducing the death-rate. At the present time the domestic administration of most of the cities and towns of Nicaragua and Panama, as well as the generality of Central American cities, is characterized

by the absence of practically everything which makes for public health, and by the presence of nearly every agency working for the diseases which flourish in tropical climates. When the United States Government reaches the point of actual construction of an isthmian canal the sanitary features of that work should be administered and enforced in every detail with the rigor of the most exacting military discipline. Under such conditions, epidemics could either be avoided or reduced to manageable dimensions, but not otherwise. The commission concluded that "Existing conditions indicate hygienic advantages for the Nicaragua route, although it is probable that no less effective sanitary measures must be taken during construction in the one case than in the other."

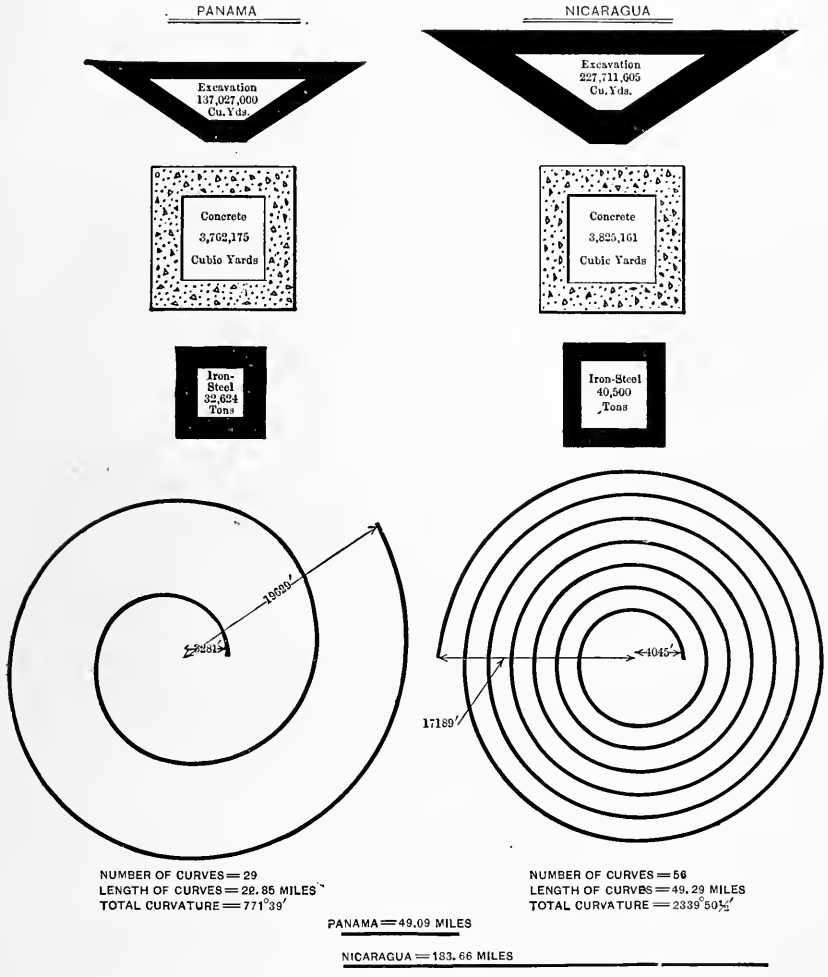
396. Time of Passage through the Canal.—The time required for passing through a transisthmian canal is affected by the length, by the number of locks, by the number of curves, and by the sharpness of curvature. The speed of a ship, and consequently the time of passage, is also affected by the depth of water under its keel. It is well known that the same power applied to a ship in deep water of unlimited width will produce a much higher rate of movement than the same power applied to the same ship in a restricted waterway, especially when the draft of the ship is but little less than the depth of water. These considerations have important bearings both upon the dimensions of a ship-canal and upon the time required to pass through it. They were most carefully considered by the commission, as were also such other matters as the delay incurred in passing through the locks on each line, the latter including the delay of slowing or approaching the lock and of increasing speed after passing it, the time of opening and closing the gates, and the time of emptying and filling the locks. It is also evident that ships of various sizes will require different times for their passage. After giving due weight to all these considerations it was found that what may be called an average ship would require twelve hours for passing through the Panama Canal and thirty-three hours for passing through the Nicaragua Canal. Approximately speaking, therefore, it may be stated that an average passage through the former waterway will require but one third the time needed for the latter.

397. Time for Completion on the Two Routes.—The time in which an isthmian canal may be completed and ready for traffic is an element of the problem of much importance. There are two features of the work to be done at Panama, each of which is of sufficient magnitude to affect to a controlling extent the time required for the construction of the canal, viz., the Bohio dam and the Culebra cut. Both of these portions of the work may,

A Street in Panama.

however, be prosecuted concurrently and with entire independence of each other. There are no such features on the Nicaragua route, although the cut through the divide west of the lake is probably the largest single work on that route. In considering this feature of the matter it is well to observe that the total amount of excavation and embankment of all grades on the Nicaragua route is practically 228,000,000 cubic yards, while that remaining to be done on the Panama route is but little more than 97,000,000 cubic yards, or 43 per cent of the former. The

accompanying figures show the relative quantities of total excavation, concrete, iron, and steel required in construction along the two routes, as well also as the total amounts and radii of curvature.



Diagrams comparing some of the main Elements of the two Routes.

The commission has estimated ten years for the completion of the canal on the Panama route and eight years for the Nicaragua route, including in both cases the time required for preparation

and that consumed by unforeseen delays. The writer believes that the actual circumstances attending work on the two routes would justify an exchange of these time relations. There is great concentration of work in the Culebra-Emperador cut on the Panama route, covering about 45 per cent of the total excavation of all grades (43,000,000 cubic yards), which is distributed over a distance of about 7 miles, with the location of greatest intensity at Culebra. This demands efficient organization and special plant so administered as to reduce the working force to an absolute minimum by the employment of machinery to the greatest possible extent. A judicious, effective organization and plant would transform the execution of this work into what may be called a manufactory of excavation with all the intensity of direction and efficiency of well designed and administered machinery which characterizes the concentration of labor and mechanical appliances in great manufacturing establishments. Such a successful installation would involve scarcely more advance in contract operations than was exhibited, in its day, in the execution of the work on the Chicago Drainage-canal. By such means only can the peculiar difficulties attendant upon the execution of great works in the tropics be reduced to controllable dimensions. The same general observations may be applied to the construction of the Bohio dam, even should a no more favorable site be found.

The greatest concentration of excavation on the Nicaragua route is between the lake and the Pacific, but it constitutes only 10 per cent of the total excavation of all grades, and it can be completed in far less time than the great cut on the Panama route. If this were the only great feature of work besides the dam, the time for completion of work on this route would be materially less than that required for the Panama crossing. As a matter of fact, there are a succession of features of equivalent magnitude, or very nearly so, from Greytown nearly to Brito, extending over a distance of at least 175 miles, requiring the construction of a substantial service railroad over a considerable portion of the distance prior to the beginning of work. This attenuation of work requires the larger features to be executed in succession to a considerable extent, or much duplication of plant

and the employment of a great force of laborers, practically all of whom must be foreigners, housed, organized, and maintained in a practically uninhabited tropical country where many serious difficulties reach a maximum. It is not within the experience of civil engineers to execute by any practicable means that kind of a programme on schedule time. The weight of this observation is much increased when it is remembered that the total volume of work may be taken nearly twice as great in Nicaragua as at Panama, and that large portions between Lake Nicaragua and the Caribbean Sea must be executed in a region of continual and enormous rainfall. It would seem more reasonable to the writer to estimate eight years for the completion of the Panama Canal and ten years for the completion of the Nicaragua Canal.

398. Industrial and Commercial Value of the Canal. — The prospective industrial and commercial value of the canal also occupied the attention of the commission in a broad and careful study of the elements which enter that part of the problem. It is difficult if not impossible to predict just what the effect of a transisthmian canal would be either upon the ocean commerce of the United States or of other parts of the world, but it seems reasonable to suppose from the result of the commission's examinations that had the canal been in existence in 1899 at least 5,000,000 tons of the actual traffic of that year would have been accommodated by it. The opening of such a waterway, like the opening of all other traffic routes, induces the creation of new traffic to an extent that cannot be estimated, but it would appear to be reasonable to suppose that within ten years from the date of its opening the vessel tonnage using it would not be less than 10,000,000 tons.

The Nicaragua route would favor in distance the traffic between our Atlantic (including Gulf) and Pacific ports. The distances between our Atlantic ports and San Francisco would be about 378 nautical miles less than by Panama. Between New Orleans and San Francisco this difference in favor of the route by Greytown and Brito would be 580 nautical miles. It must be remembered, however, that the greater time by at least twenty-four hours required for passage through the Nicaragua Canal practically obliterates this advantage, and in some cases would

throw the advantage in favor of the Panama waterway. This last observation would hold with particular force if for any reason a vessel should not continue her passage, or should continue it at a reduced speed during hours of darkness, which could not be escaped on the Nicaragua Canal, but might be avoided at Panama. For all traffic between the Atlantic (including Gulf) ports and the west coast of South America the Panama crossing would be the most advantageous. As a matter of fact, while there may be some small advantage in miles by one route or the other for the traffic between some particular points, on the whole neither route would have any very great advantage over the other in point of distance or time; either would serve efficiently the purposes of all ocean traffic in which the ports of the United States are directly interested.

The effect of this ship waterway upon the well-being of the United States is not altogether of a commercial character. As indicated by the commission, this additional bond between the two portions of the country will have a beneficial effect upon the unity of the political interests as well as upon the commercial welfare of the country. Indeed it is the judgment of many well-informed people that the commercial advantages resulting from a closer touch between the Atlantic and Pacific coasts of the country are of less consequence than the unifying of political interests.

In a final comparison between the two routes it is to be remembered that the concession under which the new Panama Company has been and is now prosecuting its work is practically valueless for the purposes of this country. It will therefore be necessary to secure from the republic of Colombia, for the Panama route, as well as from the republics of Nicaragua and Costa Rica, for the Nicaragua route, such new concessions as may be adequate for all the purposes of the United States in the construction of this transisthmian canal. The cost of those concessions in either case must be added to the estimated total cost of the work, as set forth, in order to reach the total cost of the canal along either route:

399. Comparison of Routes.—Concisely stating the situation, its main features may be expressed somewhat as follows:

Both routes are entirely "practicable and feasible."

Neither route has any material commercial advantage over the other as to time, although the distance between our Atlantic (including Gulf) and Pacific ports is less by the Nicaragua route.

The Panama route has about one fourth the length of that in Nicaragua; it has less locks, less elevation of summit level, and far less curvature, all contributing to correspondingly decreased risks peculiar to the passage through a canal. The estimated annual cost of operation and maintenance of the Panama route is but six tenths that for the Nicaragua route.

The harbor features may be made adequate for all the needs of a canal by either route, with such little preponderance of advantage as may exist in favor of the Panama crossing.

The commission estimated ten years for the completion of the Panama Canal and eight years for the Nicaragua waterway, but the writer believes that these relations should be exchanged, or at least that the time of completion for the Panama route should not be estimated greater than for the Nicaragua.

The water-supply is practically unlimited on both routes, but the controlling or regulating works, being automatic, are much simpler and more easily operated and maintained on the Panama route.

The Nicaragua route is practically uninhabited, and consequently practically no sickness exists there. On the Panama route, on the contrary, there is a considerable population extending along the entire line, among which yellow fever and other tropical diseases are probably always found. Initial sanitary works of much larger magnitude would be required on the Panama route than on the Nicaragua, although probably as rigorous sanitary measures would be required during the construction of the canal on one route as on the other.

The railroad on the Panama route and other facilities offered by a considerable existing population render the beginning of work and the housing and organization of the requisite labor force less difficult and more prompt than on the Nicaragua route.

The greater amount of work on the Nicaragua route, and its distribution over a far greater length of line, involve the employ-

ment of a correspondingly greater force of laborers, with greater attendant difficulties, for an equally prompt completion of the work.

The relative seismic conditions of the two routes cannot be quantitatively stated with accuracy, but in neither case are they of sufficient gravity to cause anxiety as to the effects upon completed canal structures.

Concessions and treaties require to be secured and negotiated for the construction of the canal on either route, and under the conditions created by the $40,000,000 offer of the new Panama Canal Company this feature of both routes appears to possess about the same characteristics, although the Nicaragua route is, perhaps, freer from the complicating shadows of prior rights and concessions.