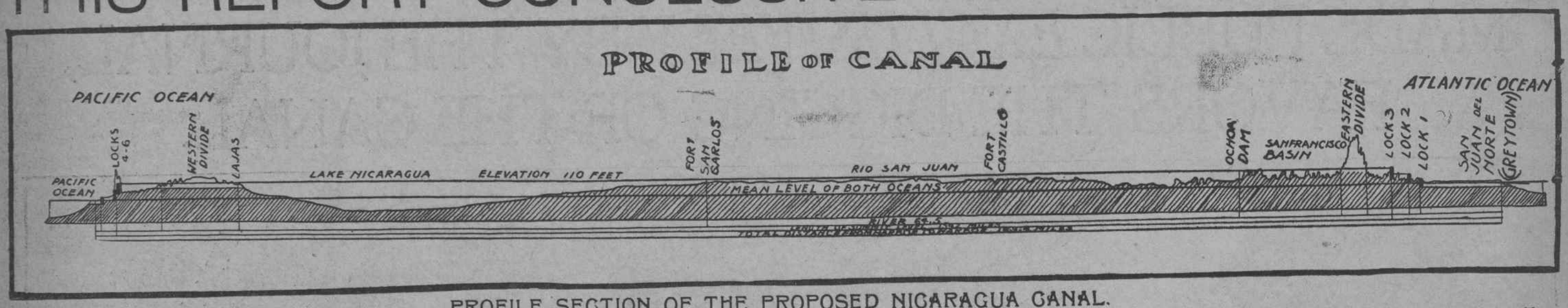
THIS REPORT CONCLUSIVE AS TO NICARAGUA.



PROFILE SECTION OF THE PROPOSED NICARAGUA CANAL.

This map shows, markedly, some of the points on which the Walker Commission so strongly insists. There is a long upper level, that will be as easy of navigation as the Great Lakes and the St. Lawrence. At either end of the line, huge locks will make the connection with the two oceans. The difference in water level between the Atlantic and Pacific will be a striking feature to those who believe that the oceans ought to be the same, as they are really one body of water.

The land on the Eastern Divide rises to a greater height than that on the Western Divide, but the San Juan River, with its waters thrown up and back by an enormous dam, will make the passage of the greater part of the divide easy. The absence of any large number of locks and the long stretch of straight sailing would alone make the huge work a marvels among the great canals of the world.

The Enlarged Commission Will Next Investigate the Panama Scheme, and the Report Now Given Publicity Exclusively by the Journal Will Then be Published Officially, Together with That on the Panama Canal Project.

Toro to the foot of the Machuca, embracing the four rapids, the fall is nearly forty-three feet in twenty-three miles, or twenty-two and one-half inches per mile. This comprises the rocky section of the ancient Continental Divide, and is the gorge of the river valley.

Below Machuca occurs a stretch of about fifteen miles of deep water, the bottom of which extends in places below sea level, known as the Agua Muerta (dead water). This is a portion of the old river channel not silted up by the volcanic sands brought into the Lower San Juan by the San Carlos River.

BANKS OF THE RIVER FOUND VERY STABLE.

Flow Found to Be Very Heavy, but Chiefly Confined to the River Bed.

This sand becomes a characteristic feature of the entire lower reach of the river and its delta from this point to the sea. It is confined, however, mainly to the bed of the channel, the banks through the hill country being the stiff clays resulting from the weathering of the rocks of the region.

These banks are remarkably stable, notwithstanding the heavy rains and large volume of water which sweep past their bases at high stages.

As the bend of the upper river forms an important part of the route a more detailed description of it is believed to be necessary. The slope, as given by the survey and corrected for stage, may be stated to best advantage in tabular form. This, taken with the cross sections, velocity and volume of discharge as stated in detail in the accompanying reports of the assistants, will show the characteristics of the streams in a state of nature.

The Upper River.

Reach.	Distance. miles.	Fall. feet.	Rate of fall, per mile. feet.
From the lake to Sabalos	27.16	5.4	0.198
Sabalos to foot of Toro Rapids	1.70	7.3	4.294
Toro to head of Castillo	7.98	1.2	0.150
Castillo to bottom of rapids	0.38	6.0	15.789
Castillo to head of Balas Rapids	2.08	2.5	1.202
Palma to one mile below Machuca	10.62	26.0	2.448
Machuca to Boca San Carlos	14.79	1.0	0.067

The Lower River.

Reach.	Distance. miles.	Fall. feet.	Rate of fall, per mile. feet.
San Carlos to San Juanillo	33.02	30.0	0.908
San Juanillo to Colorado	5.28	4.0	0.757
Colorado to sea (via San Juan)	18.65	21.0	1.128
Lake to sea	121.66	104.4	0.86 av.

Slopes Always Varying.

The slopes are, however, constantly varying with the stage and local conditions. A heavy rainfall on the San Carlos basin may reverse the slope for a time in the Agua Muerta, causing the water to run up stream.

At Sabalos, where the slope is about 2½ inches per mile, the maximum velocities and discharges as observed were reported as follows.

	Cross section in square feet.	Mean velocity, feet per second.	Discharge, cu. ft. per second.
Jan. 21, 1898	8,819	2.16	19,090
Feb. 21, 1898	8,576	1.92	16,550
Sept. 11, 1898	11,273	1.95	21,998
Sept. 14, 1898	10,684	2.12	22,679
Sept. 21, 1898	10,720	2.09	22,433
Dec. 3, 1898	11,273	2.39	26,700

In the upper reaches, the slope being very flat, the river carried over 20,000 cubic feet through sections of over 10,000 square feet at velocities exceeding 2 feet per second, with corresponding increase at the gorges and rapids.

The Maximum Velocities.

At Ochoa Station, about sixty-nine miles from the lake, the banks are steep clay slopes. The bed of the river consists of black sand of the same character as that composing the sea beach near Greytown.

In a state of nature the mean velocity of the stream is frequently over four feet per second, and at times exceeding five, while the lower river discharges over 50,000 cubic feet per second, and occasionally over 100,000, with perceptible effect upon the banks.

The slopes of the stream, therefore, vary from about one inch per mile in the Agua Muerta to six feet in one-third of a mile on the Rapids of Castillo, and the velocity from less than one foot per second to over twelve, while the recorded discharge at Ochoa ranges from 16,145 to 104,930 cubic feet per second.

To pass the Castillo Rapids at low stages of the river a tramway has been constructed under the brow of the hill for the purpose of transferring passengers and freight. The width of the upper river is quite variable. It ranges from about 350 feet to 1,200 feet.

Its general alignment is direct, but there are several sharp horseshoe curves where cut-offs would be required across alluvial flats, by which over five miles of distance would be saved.

The Lateral Drainage.

The principal tributaries from the Costa Rican side are the Rio Frio, Poco Sol, San Carlos and Sarapiqui, the former emptying into the lake just at the head of the river. These large streams exert a controlling influence in confining the location of the canal to the left bank.

The streams on the left bank are the Melchora, Palo de Arco, Negro, Sabalos, Machuca, La Cruz, Machado, Danta, San Francisco and others, none of which has a large drainage basin. They have many small branches permeating the swamps and ravines which characterize the broken topography of this section.

On reaching the edge of the coastal plain the river drainage is distributed through the San Juanillo, Colorado, lower San Juan, Taura, and their branches, Parado and Cano Bravo, leading to the sea.

The Discharges Computed.

The minimum computed discharge of the upper river at the Sabalos station during 1898 was found to be 11,206 cubic feet per second on May 13, while the maximum occurred on November 13, when it was 28,480 feet, the difference in stage being 5.59 feet. At Ochoa, below the mouth of [illegible], the minimum computed [illegible] 19 was 16,300, and [illegible] was 107,000 cubic feet per second on November 17, the variation in stage being 13.35 feet.

To provide for extreme cases, however, it is estimated that the river above the San Carlos may, at rare intervals, under the cumulative discharges from the lake and river, reach a possible maximum of 100,000 second-feet, and that the San Carlos, a flashy and torrential stream, may add 100,000 more to this quantity in the lower section for a short time.

A CHANNEL 300 FEET WIDE, 30 FEET DEEP.

Vegetation Clothes the Surface with a Thatch, Protecting It Against Floods.

The entire river bed has been carefully surveyed, with a view to determine its carrying capacity under the regimen resulting from the creation of such dams and locks as may be found best adapted to convert it into a navigable channel for deep draught vessels.

The upper river will require dredging from the lake to the Castillo rapids, and as the channel as proposed will be 300 feet wide at bottom and extend to a depth of thirty feet below the lowest lake level this cut will largely increase the cross section and thus enable a larger volume to be discharged without any material increase of velocity.

Moreover, the river falls about 13.9 feet below the 105 stage in the lake before reaching the head of the Castillo Rapids, so that a dam farther down stream impounding this water would still further augment the cross section by raising the surface. As the capacity is regulated by the smallest sections it is necessary to ascertain their location and effects upon the discharge under the new regimen.

The Controlling Sections.

Under existing conditions the ruling sections of the stream are found to be at the head of the Toro Rapids and Castillo Rapids in that section of the upper river between Port San Carlos and the Castillo Viejo.

It appears that the location of the controlling section would be changed from its present position to a point five miles from the lake, while the area of that section would be very nearly doubled at a lake elevation of 110 above tide.

As the maximum discharge required to pass through this section, with a range of six feet for the greatest fluctuation, would not produce velocities exceeding 3.3 feet per second, such a discharge would not materially affect the stability of the channel nor its navigation.

Instead of having velocities exceeding 12 feet per second over the rapids, which would be submerged, the maximum current in the river under a discharge of 30,000 cubic feet would not exceed 2 feet, or 1½ miles per hour, which would not readily disturb the banks of this section of the stream. Under ordinary conditions and throughout nearly this entire reach the velocities would be less than one foot per second.

With a discharge of 50,000 cubic feet, which is higher than will probably ever be reached in this (upper) part of the river, the maximum velocity through the controlling sections would not, therefore, much exceed 3 feet per second, imposing no material restrictions on navigation.

Compensations of Nature.

So much stress has been laid upon the excessive precipitation and its destructive effects upon the proposed works, as well as upon the labor and machinery required, that the Commission is impelled to call attention to the fact that the physical features of the country furnish the most convincing and conclusive evidence that these uncontrolled forces are not so injurious as has been alleged, for the angle at which freshly made earth slopes stand is found to be much steeper than that prevailing in our more northern latitudes, where they are also exposed to the destructive action of frost and the internal stress due to greater range of temperature.

In some cases in the northwest the range covers 160 degrees, whereas in Nicaragua the greatest fluctuation seldom exceeds 25 degrees. The absence of frost more than compensates for the excessive downpour.

Nature compensates for the greater rainfall by the uniformity of heat and moisture. The spontaneous growth of vegetation reverts the natural surface, clothing it with a protecting thatch, which not only acts as an elastic cushion to break the impact, but also to retain the water, and thus prevent the sudden and destructive floods so familiar to us during the Spring.

Much Volcanic Sand.

The board of 1895, in referring to the character of the work done in Greytown harbor, remarks that "the material excavated was almost entirely volcanic sand, similar to that of the beach. * * * When piled in heaps it forms a porous mass, through which the torrential rainfalls descend with surprisingly little effect upon its contour, even though the slopes be steep."

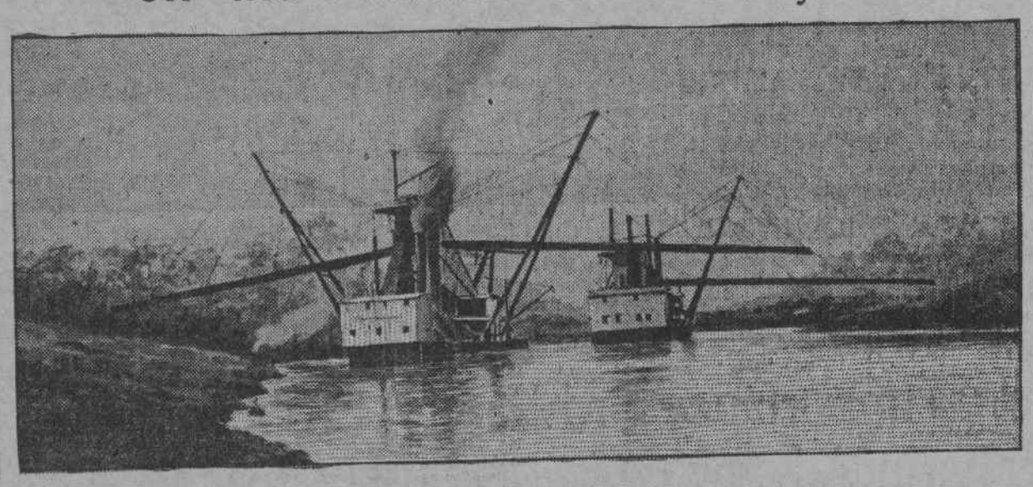
Of the cuts along the railroad the board also adds: "The cuts have heights up to twenty feet, with slopes from vertical to forty-five degrees, and in most cases stood with an extraordinary stability under the tropical downpour. The surface of the cuts was in some cases protected by vines, but in most was quite bare unless for a minute lichen.

"As these clay cuts have been exposed for over three years to the severest rainfall of record on this continent and were found in better condition on the whole than an exposure in the United States for a single Winter would have left them, it is evident that the absence of frost more than balances the tropic downpour, and for the material in question constructions can quite as safely be designed as in the United States.

"On the whole, taking into account the condition of the sand dumps at Greytown and of the clay cuts and fills on the line of the railroad, it is evident that the heavy rainfall is not necessarily as formidable an obstacle to outdoor construction as might be supposed."

The geologist, Dr. Hayes, also states, concerning the resistance of the slopes to erosion on the western division, that:

"The present channel of the Rio Grande is from fifteen to twenty-five feet in depth and its sides are generally steep, often nearly or quite vertical. They serve to show the capacity of the material to stand at very steep slopes."



Dredges in the Harbor of Greytown.

Greytown Harbor is the eastern terminus of the line of the canal. The dredges shown in the view are at work on the first mile of the route. The accumulation of drifting sand in Greytown Harbor is one of the chief problems that face the canal contractors, but the commission has found that the difficulty can readily be overcome.

RISKS FROM DISEASE ARE VERY SLIGHT.

Natives Suffer Little from Fevers, and Americans Can Keep Healthy.

The impression that this portion of the isthmus is unusually unhealthy is erroneous. On the contrary, the local conditions are such that, with ordinary hygienic precautions, the risks from disease are slight.

The frequent rainfall on the east coast furnishes an ample supply of fresh, soft water condensed directly from the clouds; the porous, sandy soil absorbs it so rapidly as to prevent stagnation, while animal refuse is quickly removed by the scavenger birds and fish continually on the alert for food.

With their light, loose clothing, vegetable diet and cleanly habits, the natives seldom suffer from fevers. Even our unacclimated Americans passing from a rigorous Winter temperature to the mild region of the trade winds were, with few exceptions, exempt from febrile complaints, and among the large number of engineers sent out there was no mortality in the country.

The constant motion of the wind, sweeping through this low divide, appears to remove the noxious exhalations which characterize other portions of the isthmus. Yellow fever finds no habitat at Greytown, and even when imported it does not become epidemic.

Abstemious habits and careful police of camps will insure as good health among laborers as will be found in many localities in this country. The climate would affect the labor question, therefore chiefly by the lassitude resulting from the enervating influence.

Range of Temperature.

The narrow limits within which the temperature ranges is shown from a few selected observations at various stations during the year as below. The Rio Viejo station is located on the western slope of the Cordilleras east of the lake and at a higher altitude than the others. Hence its greater range of 30 degrees:

Exhibit of extreme range of the observed temperature in Nicaragua.

Date, 1898.	Maximum.	Minimum.	Date, 1898.	Range
Brito and Tola Stations—				
Dec. 22	95°F.	75°F.	June 28	13°
Las Lajas Station—				
May 12	91°	73°	Sept. 10	18°
Rio Viejo Station—				
Mar. 3	97°	62°	Mar. 12	35°
Fort San Carlos Station—				
May 8	91°	70°	Mar. 28	21°
Sabalos Station—				
Mar. 20	95°	65.2°	Dec. 25	24.8°
San Carlos River—				
May 7	95°	66°	Feb. 7	29°
Ochoa Station—				
Oct. 1	95°	66.5°	Jan. 3	28.5°
Deseado River Station—				
May 25	91°	65°	Jan. 3	26°
Greytown—				
Sept. 20	96°	69°	Mar. 14	27°

Volcanoes and Earthquakes.

From the most reliable data obtainable, the commission believes that the canal region is practically exempt from any seismic influences of sufficient force to cause destruction or danger to any part of the canal route or suspension of its traffic.

Dr. C. W. Hayes has treated this question fully in his report. He says:

"Earthquakes due to the dislocations of strata (faults) are perhaps no more liable to occur in the vicinity of the Nicaragua Canal route than elsewhere, and hence they do not constitute a danger which is peculiar to this region more than to almost any other in which a ship canal might be constructed."

He then proceeds to discuss those due to volcanic agencies at some length, and concludes that those activities are on the wane, and so remote from the route as not to constitute a menace. In quoting from Major Dutton, he adds:

"Briefly, then, the risk of serious injury by earthquakes to the constructions proposed for the Pacific section of the canal is so small that it ought to be neglected. * * * Also, that the risks to the Atlantic section are still smaller than those to the Pacific section."

Material for Construction.

The cost and durability of the canal are also affected by the character and distribution of such native material as may be utilized for the purposes of construction. These consist chiefly of earth, rock, timber and sand, all of which are abundant and free. Cement, iron, explosives, tools, plant and some provisions and clothing will need to be imported, but will be exempt from duty.

Dr. Hayes, in his report, says:

"The alluvium is everywhere of such character that it can be easily handled with dredges. Almost everywhere the silt and clay-silt are sufficiently solid to stand at moderate slopes. In some cases, as in the Florida lagoon, special precautions may be needed to preserve the slopes.

"The material becomes very hard when dry, and even when it is piled up so that the water can drain off it becomes comparatively firm. It is probable that wherever the canal is more than half in excavation, the silt will form banks sufficiently impervious to hold the required height of water without the addition of any other material."

Black Volcanic Sand.

The black volcanic sand of the east coast and lower river section is not composed of the partly decayed minerals derived from a deeply weathered rock, but is made up entirely of finely comminuted fragments of fresh volcanic rock, evidently broken up and ejected by explosive volcanic eruptions.

It would thus make a good, sharp, clean material for hydraulic mortar, concrete or beton. Its specific gravity is 1.68, or 104 pounds per cubic foot, comparing very favorably with the best building sand in the United States.

Clay of excellent quality is abundant and well distributed. When mixed in suitable proportions with sand and gravel it makes an admirable building material.

Numerous large trees occur in the forests along the river and on the border of the lake, which are denser and stronger than our American oaks and pines. The clearing of the canal route will also furnish a large number of cross-ties.

Some of these native woods, according to Colonel Childs, will last above ground from forty to fifty years. The Madeira negro is one of the most valuable for ties, and is abundant. It may also be obtained for dimension timber up to thirty-feet lengths and eleven inches square.

The nispera will cut in lengths of fifty feet and square eighteen inches. It is very common and durable, but heavy. Many other varieties exist, as the Palo Cortez, Gauchipilin, Roble, Cocobole, Grenadia Palo de Arco, Guanadillo, Guayacan, Almendro, Feniscaro, etc. The shipment of timber is one of the industries of the port of San Juan del Sur.

PLENTY OF SHELTER IS TO BE FOUND.

Climatic Conditions Favorable to the Preservation of Iron and Steel.

There is ample material available without cost for the protection of men and materials from rain and sun. The usual habitations of the natives consist of a carefully laid thatched roof, substantially built, reaching nearly to the ground, with walls of bamboo or adobe. These afford free circulation of air and are cool and dry. Their only cost is for the labor of erection, which is slight.

The fuel in general use is wood, which is cut and stacked under shelter on the banks of the river. A considerable quantity of cordwood can be secured from the clearing of the route and the adjacent forests. In some localities water power may be made available.

Iron and steel will necessarily be imported, but the climatic conditions are such as to cause remarkably little deterioration. Templates of the rails which have been exposed to the rain and sun for about nine years do not exhibit any measurable loss in section of weight.

Only where the salt water of the ocean reaches the iron rails and bolts on the pier is there any considerable amount of scale visible.

Sandstone Near Brito.

A large amount of material on the route of the canal, classified as rock and soft rock, will require excavation to create the channel. A portion of this is suitable for structural purposes. On the western division the rock is generally a calcareous nonfissile shale, interstratified with beds of sandstone varying from a few inches to two or three feet in thickness.

About half a mile east of Brito is found a group of heavy sandstone beds forming a spur extending into the Rio Grande Valley. These beds would probably yield a good quality of dimension stone; would be easily quarried in dimensional blocks up to twenty or more inches in thickness; would dress readily and [illegible] as durable as the average sandstone.

North of the canal line at Bueno Retiro is a large deposit of intruded andesite or trap which makes a very desirable material for structural purposes.

The rocks on the eastern division are chiefly of igneous origin, but from a few miles below Castillo to half way between Machuca and Boca San Carlos they are largely sedimentary with a few small igneous dikes.

Varieties of Rock.

The principal varieties of the igneous rock found in this section are augito-andesite, olivine basalt, hypersthene basalt and dacite. The first three are commonly known as trap rock. They are generally compact and heavy. The dacite is lighter than the trap, and somewhat softer.

The basalt (trap) extends from the Boca San Carlos eastward beyond the San Francisco Hills, forming the Serapiqui Hills and others bordering the lower portion of the San Juan River, as well as those in the vicinity of Silico Lake, and is suitable for dams, jetties and concrete.

The dacite is found at Lower Ochoa and Tambor Grande, where it comes to the surface, and continues to the Eastern Divide. It is there interbedded with the andesite tuffs and basalt.

Associated with the above-named massive rocks is a group of fragmental igneous rocks, whose members vary from coarse conglomerate or breccia to beds of fine volcanic ash. The coarser varieties resemble in their physical properties the igneous rocks from which they are derived, while the fine ash is generally talcose and crumbles on exposure to the air.

Several outcrops of rock reported to be suitable for jetty construction exist on the coast at Point of Rocks and at Monkey Point. The quarries are readily accessible from the sea and furnish material for ballast to coasters.

Some Blasting Needed.

The three classes of materials—alluvium, residual clay and soft rock—should be considered as earth in making estimates for excavation. The soft rock, however, may require some blasting, particularly toward the bottom and where it contains very large boulders. It will stand with much steeper slopes than the silt and clay, and will be less liable to slip.

Not being plastic, it will also support a heavier load, and hence may be relied upon for foundations where the weight of the structure is not excessive. For these reasons, it seems desirable to make the distinction between clay and soft rock wherever possible.

The weathering of rocks is brought about by two processes—rock disintegration and rock decay. The first varies directly and the second inversely with latitude when humidity is constant. The first proceeds depends on changes of temperature and expansion of interstitial water by freezing, hence is inactive in the tropics.

The second process depends on higher temperature and a rapidly decaying vegetation, hence is active in the tropics. Special attention is directed to the fact that it is chiefly the first process of disintegration which is inimical to the permanence of structures, and hence that their relative durability will be greater in the tropics than in higher latitudes.

Such being in brief the physical conditions of the route, it remains to determine the dimensions which, all things considered, will best subserve the interest of the world's commerce in making this transit of the isthmus.

DIMENSIONS FIXED FOR THE CANAL.

Depth 30 Feet, and the Locks 80 Feet Wide and 665 Feet Long.

To provide ample facilities for the safe and expeditious passage of vessels, the trunk of the waterway has been considerably enlarged over that of any previous project. The dimensions adopted by the Commission as the basis of the estimates are as follows:

The canal nowhere to be less than thirty feet in depth. The width varying with the local conditions as follows: From Greytown harbor to Boca San Carlos the bottom width to be 150 feet, with slopes in earth of 1:1 and in alluvial salt of 1:2. In hard rock vertical sides 40 feet from the bottom, with slopes 5:1. In soft rocks the slopes to be 2:1.

In the river the width at bottom to be 300 feet, with slopes of 1:2, with enlargements at the bends, and at the eastern end of the lake the excavation to be 600 feet wide at the outer end, decreasing to 300 feet at the river, and having slopes of 1:5 to the depth of 6 feet and then 1:3. For all routes from the Caribbean Sea to the lake, excepting the Menocal route, the same dimensions are used.

The bottom width of the canal from the lake to the Pacific to be 150 feet, with slopes as on the east side, and the computations have been based upon a minimum lake elevation of 104 above mean sea level, Caribbean Sea as a datum. The minimum radius is limited to 3,000 feet, with enlargements of width in bends varying according to the degree of curvature.

The locks are 80x30x665 between quoins, giving an available length of 630 feet with variable lifts.

Estimates were also made upon numerous modifications of the above dimensions.

Area of Cross Sections.

For convenient reference and comparison with the canal prism as proposed by the Maritime Canal Company, the areas of the several cross sections and the percentages of increase are stated herewith:

Area of cross sections in square feet—		P. C. of increase.
Between jetties, Greytown	23,400	—
Entrance to harbor, Greytown	14,700	—
Coastal section	6,800	10.3
Canal proper	5,460	9.1
Through rock	4,500	50.0
In the river (in rock)	9,900	131.0
In the river (in earth)	10,800	84.0
In the lake	7,272	73.0
	13,272	216.0
WEST SIDE.		
Western divide	4,500	50.0
Across coastal plain	5,850	8.0 less

Distances along the line of the canal route proposed by this commission, from the seven fathom curve in the Pacific Ocean to the seven fathom curve in the Caribbean Sea—

1. Brito Harbor	0.93
2. Brito to Buena Retiro	8.04
3. Bueno Retiro to west side of lake	8.71
4. Lake Nicaragua	71.34
5. East side Lake Nicaragua to Boca San Carlos	56.96
	21.59
6. Boca San Carlos to Saripiqui	20.59
7. Saripiqui to Greytown	1.74
8. Greytown Harbor	
Total	189.99

Lake as Summit Level.

All plans for a canal by the Nicaragua route contemplate using the lake as the summit level for the canal and as a feeder. The regulation of its level is therefore a matter of the greatest importance.

It is known with reasonable certainty that the lake has varied in its elevation above sea level as much as 13 feet. It has probably been as low as 98 feet above mean sea level, and as high as 111 feet above the same plane. These extremes have occurred at relatively remote intervals, but their occurrence in the absence of regulating works must be reasonably anticipated.

It is also known that, notwithstanding the losses due to the outflow through the San Juan River and to evaporation, the lake has risen as much as two feet in six weeks.

The higher the lake is held the less will be the excavation in the upper level, and as this is a heavy item in the cost of construction, the effort has always been to keep that level up as high as practicable, without causing unnecessary damage to private property. On the other hand, a spillway of capacity sufficiently great to prevent the lake from rising is expensive. The problem, therefore, is how best to meet the varying conditions.

Area 3,000 Square Miles.

The area of Lake Nicaragua, in round numbers, is 3,000 square miles, nearly 2,000,000 acres. The drainage area, including both lakes, is about 12,900 square miles. During the dry season of 1898 measurements were taken to determine the total inflow into Lake Nicaragua, which was found to be only about 1,700 cubic feet per second, showing that in the dry season the inflow into the lake is scarcely worth considering. Nearly all the streams showed evidences of being stagnant several months, yet the year 1898 was one of more than average rainfall.

Observations to determine rainfall have been kept at Rivas for the last nineteen years.

Comparing the records at Rivas for the year 1898 with those for the other points it will be noted that the rainfall at Rivas was greater than the average for other parts of the basin; that at Rivas being 108 inches and the average in the basin 78 inches, a difference of about 28 per cent. in favor of Rivas.

Peculiar Topography.

This might at first appear anomalous, but it may be accounted for by the peculiar topographical features of the country in connection with the prevailing winds. It will therefore be assumed that in order to obtain the rainfall in the basin for other years than that of 1898 the Rivas record will have to be reduced by 28 per cent.

There are two distinctly marked seasons in the drainage area of the lake—the wet and the dry. The latter begins about December 15 and lasts until about May 15. The wet season then begins and lasts until December 15 following. It is probable, however, that the length of the wet and dry seasons may vary in some years.

Evaporation Measured.

The amount of evaporation as determined for the year 1898 was 52 inches. That year was an abnormally wet one and it is therefore probable that the evaporation was somewhat below the average. Mr. Davis estimates a normal annual aggregate at about 60 inches, or about five feet. The amount of evaporation in the lake itself has been taken at four inches per month during the wet period, and six inches during the dry.

These results have been checked by the Commission's study of the exhibits, as follows:

From chart No. XVI. it appears that during the year 1898, throughout which careful examinations were made, the lake fell about 3.09 feet between January 6 and May 15, a period of 131 days, or 4.5 months, while in the following season of rainfall it rose 4.72 feet by December 5, when it again began falling. The net gain in storage during this entire year from January 5, 1898, to January 5, 1899, was 15.6 inches.

Effect of the Big Wind.

It will be observed that during that portion of the season beginning February 1 and ending May 15 the lake surface declined uniformly (the slight fluctuations when due to mind and not to rainfall) and that in this time the total rainfall did not exceed 2¾ inches over the lake surface.

THIRTY PER CENT OF RAIN REACHES LAKE.

Plentiful Water Supply for Lockage and Power Purposes.

The run-off from the parched ground at this season is practically zero. Hence the only gain was the direct rainfall, while the losses were those due to evaporation and outflow.

The outflow between February 1 and May 15 is given as 2,817,748 acre feet, equivalent to a vertical depth over the lake area (2,000,000 acres) of 1,408 feet. If this be deducted from the loss in storage and rainfall, which is 2.840 feet, it leaves 1.432 feet loss due to evaporation in 104 days or a diurnal rate of .165 inches (1-6"), or 5 inches per month, or a rate of 5.00 feet per annum for a dry year. This being deducted during the dry season would doubtless represent the maximum for the year.

Inflow to the Lake.

The run-off or inflow to the lake, from rainfall on its drainage basin, exclusive of the lake proper, for the year 1898 has been found to be about 30 per cent of the rainfall. This is computed as follows:

The average rainfall at six stations in the basin of Lake Nicaragua for 1898 was 78.29 inches. During that year the lake rose 18 inches. The outflow, if held, would have raised the lake 84 inches. Evaporation as determined was 52 inches, so that if there had been no outflow or evaporation the lake would have risen 154 inches. Of this, 78.29 was by direct fall on the lake, leaving 75.7 inches as the rise due to the fall on the land or the run-off.

The area of the lake is 3,000 square miles; the area of the tributary basin is 9,900 square miles. The latter is, therefore, 3.3 times that of the former. Dividing the inflow into the lake, 75.7 inches, by 3.3, the ratio of the lake surface to the exterior drainage, we have 22.94 inches as the rise due to run-off. This is 29.3 per cent of the rainfall.

Estimate for Lockage.

When the canal is built the lake will be drawn upon for water for lockage and for power. There will also be some lockage, the amount depending largely upon the king of dams and wasteways used. The estimate for lockage is necessarily arbitrary, but a computation based on large traffic through the canal gives three inches as the estimate for annual requirements for lockage, leakage and power.

The surface of the lake is acted upon by several opposing forces. They must be so regulated that its fluctuations can be controlled within proper limits. Evaporation, outflow and use of the canal will lower the lake's level. Rainfall and inflow will raise it.

Water must therefore be stored for evaporation and use, and the excess of rainfall and inflow be discharged. For purposes of storage against evaporation years of minimum rainfall must be considered, and for determining spill-way capacity years of maximum rainfall.

Records of Great Value.

With the records for 1898 in connection with the rainfall records of Rivas for the past nineteen years conclusions may be reached which, while they may not be absolutely correct, will be sufficiently close for all practical purposes.

The year of minimum rainfall, as determined by the Rivas record, is 1890. During that year 31.81 inches of rain fell. If this be reduced by 28 per cent, the difference between Rivas and the average of other parts of the basin, we have 22.9 inches as the average for the basin in an extreme dry year.

It is probable that this estimate is too low. Twenty-eight inches have therefore been assumed as the minimum annual rainfall in the basin.

Estimated Run-Off.

The estimated run-off for 1898 was 29.3 per cent of the rainfall, and as the run-off will diminish with the diminution of the rainfall, 25 per cent of the rainfall has been taken as the average for a dry year. We then have 28 inches falling directly on the lake and 28 inches on the drainage area tributary thereto. The latter being about 9,900 square miles, enough water would fall on the land to raise the lake 23.1 inches. This added to that falling direct will raise the lake 51.1 inches if all sources of loss are cut off.

But the loss from evaporation would be about 60 inches, and three inches would be lost by lockage, leakage and use—a total of 63 inches or 5 feet and 3 inches. There would then be a deficit of 11.9 inches at the end of the year. If the year ends with the end of the wet period the succeeding dry period will be begun with this deficit.

For this period, lasting about five months, during which the lake would receive practically no rain, and evaporation would be at the maximum, the loss to the lake would be 30 inches for evaporation and 1¼ inches for lockage, leakage, etc.; total loss 31½ inches, which, added to the deficit of 11.9 inches, gives 43.4 inches as the deficit at the beginning of the wet season, when the lake would probably fill up again.

Temporary storage of about 4 feet in the lake is therefore needed to provide for evaporation and use in a time covering two dry periods and one wet one. In other words, if the lake had been at 108 at the beginning of the first dry period, it would have fallen to 104 at the end of the succeeding dry period.

Danger of Too Much Water.

In a year of maximum rainfall and minimum evaporation the conditions are reversed. The problem will be to get rid of surplus water and prevent the lake from rising to a high level.

The year of maximum rainfall, according to the Rivas record, was in 1887, when 12.. inches fell. Reducing this by the 28 per cent ratio we have a rainfall in the basin of 28.6 inches for the maximum year. As before stated, the variation in annual rainfall over a large area is not as great as it is at one station.

It is, therefore, probable that the en-