

LETTER OF TRANSMITTAL.

FLORIDA EVERGLADES ENGINEERING COMMISSION,
Miami, Fla., October 25, 1913.

To the board of commissioners, Everglades drainage district, and the trustees of the Internal Improvement Fund, State of Florida: Hon. Park Trammell, governor, *ex officio* president; Hon. W. V. Knott, comptroller; Hon. J. C. Luning, State treasurer; Hon. T. F. West, attorney general; Hon. W. A. McRae, commissioner of agriculture.

GENTLEMEN: I transmit herewith the report of the Florida Everglades Engineering Commission prepared in accordance with certain articles of agreement between yourselves and myself made and entered into on the 30th day of April, 1913.

The first article of said agreement is that I, "The engineer, shall organize a board of engineers to be known as the Everglades Engineering Commission (hereinafter referred to as the Engineering Commission). That the said commission shall consist of Isham Randolph, who shall be chairman, Marshall O. Leighton, representing the J. G. White Engineering Corporation, and Edmund T. Perkins."

The commission called for by this clause of the contract was promptly organized and appropriate work assigned to its respective members.

Mr. M. O. Leighton undertook the hydrometric investigations, a work for which he is particularly well equipped, and Mr. Edmund T. Perkins undertook the surveys and mapping operations, duties for which he was exceptionally well qualified. We established headquarters in Miami May 3, 1913. The first secretary of the commission was Mr. George C. Pierce, who served efficiently and satisfactorily until June 28, when he left the service of the commission and was succeeded by Mr. George B. Hills, who had previously, until that date, been in charge of one of the survey parties employed by the commission. The conclusions and recommendations of the commission and the reasons upon which they are based and by which they are supported are given in the following report, which is accompanied by maps and plans.

I wish to here record my high appreciation of the work done by my associates and the loyal spirit in which they have cooperated with me to make this report as comprehensive and conclusive as was possible within the limits of time imposed upon us and the pecuniary resources at our command.

Respectfully submitted.

ISHAM RANDOLPH, *Chairman.*

FLORIDA EVERGLADES.

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To the board of commissioners, Everglades drainage district, and the trustees of the Internal Improvement Fund, State of Florida: Hon. Park Trammell, governor, president ex officio; Hon. W. V. Knott, comptroller; Hon. J. C. Luning, State treasurer; Hon. T. F. West, attorney general; Hon. W. A. McRae, commissioner of agriculture.

GENTLEMEN: The Everglades Engineering Commission submits this report upon the practicability of draining the Everglades, and recommendations as to the methods by which said drainage may be accomplished.

Our conclusion, based on our study of ascertained facts, is that the drainage of the Florida Everglades is entirely practicable and can be accomplished at a cost which the value of the reclaimed land will justify, the cost per acre being very small.

The solution of the Everglades drainage problem is primarily dependent upon the disposition to be made of the flood waters entering Lake Okeechobee from the north. These flood waters under present conditions pass over the south rim of the lake and spread over the Everglades, placing that great area under servitude of the surplus waters of the northern watershed. In our judgment the Everglades can best be relieved of this servitude by diverting the flood waters through a canal of adequate capacity occupying the shortest practicable route to the Atlantic Ocean or an inlet thereof. Such a canal we indicate upon our maps and report upon its dimensions and its probable cost. With these extraneous flood waters diverted as indicated, the problem of draining the Everglades is reduced to proper provision for carrying off the precipitation upon them. This can be accomplished by adding to the main canals which now traverse this territory—canals now surcharged with waters flowing out of Lake Okeechobee—other canals, the courses of which are indicated on the maps accompanying this report and herein described and recommended.

Here we inject our recommendation that the whole cost of the Okeechobee-St. Lucie Canal be not charged against the draining of the Everglades, because this canal will serve three purposes: First, to control the level of Lake Okeechobee for land drainage and flood storage; second, to provide a 12-foot navigable canal, comparable in capacity with the New York Barge Canal, to construct which that State is now spending \$108,000,000; third, to afford a water power of primary capacity of 5,000 horsepower which will return to the drainage district an income that will contribute largely toward the future maintenance of the drainage systems. The total cost of this

canal, lock system, and power plant is estimated at \$2,500,000. We believe that this investment charge should be divided approximately into three equal parts; one part to be assessed against the drainage district, another against navigation, and the third to be bonded separately against the water-power plant. We believe that the water power will justify a bond issue of about \$900,000, representing an investment of \$180 per horsepower. In the south Florida region, where power will be in increasing demand for commercial and household purposes, for pumping water for irrigation, and in the earlier periods for operating dredges in interior drainage operations, will surely find a profitable market. Present and prospective cost of fuel in that region is high; therefore power derived from fuel will also be of large cost. We believe that a gross average selling price of \$40 per horsepower year for 24-hour power is conservative under all prevailing conditions. Thus there is promised an annual income of \$200,000, which, however, does not include the possible increase in actual sales equivalent to 40 or 50 per cent in excess of actual plant capacity. This is commonly made possible by the fact that consumers do not use power continuously nor at the same periods of the day. Consequently, a market 40 or 50 per cent in excess of plant capacity may usually be supplied. The added income thus derived will surely cover all cost of administration and possibly a part of the operation costs.

Fixed charges against this plant, exclusive of transmission system, will not exceed 10 per cent on the investment, or \$90,000 annually. The residue of the annual gross income \$110,000 plus the excess income above referred to should care for all operative charges and leave a generous balance which can be applied to future drainage district maintenance.

Having made the foregoing broad declaration of our conclusions, we will give in detail the ascertained facts on which these conclusions are based.

First, however, we wish to enter our appreciative acknowledgment of information and aid extended to us by the gentlemen hereinafter named:

- Hon. David F. Houston, Secretary of Agriculture.
- Beverly T. Galloway, Assistant Secretary of Agriculture.
- S. H. McCrory, Office of Experiment Stations, United States Department of Agriculture.
- O. H. Tittmann, Superintendent Coast and Geodetic Survey.
- George Otis Smith, Director United States Geological Survey.
- R. B. Marshall, chief geographer, United States Geological Survey.
- E. P. Davis, topographer, United States Geological Survey.
- J. R. Slattery, major, Corps of Engineers, United States Army.
- J. E. Ingraham, vice president Florida East Coast Railway.
- E. Ben Carter, superintendent maintenance of way, Florida East Coast Railway.
- W. J. Krome, constructing engineer, Florida East Coast Railway.
- V. W. Helm, president Everglades Land Sales Co.
- J. W. Kackley, chief engineer, Everglades Land Sales Co.
- John T. Stewart, professor of agriculture, University of Minnesota.
- Hon. W. S. Jennings.
- F. C. Elliot, acting chief drainage engineer.
- Capt. J. L. Megathlin, of Furst-Clark Construction Co.

Prof. Charles F.
Dr. Luman J. B.
J. L. Porter, dir.
George C. Earl
and water boar
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Prof. Charles F. Marvin, Chief, United States Weather Bureau.
 Dr. Lyman J. Briggs, physicist, Bureau of Plant Industry.
 J. L. Porter, director, New Orleans water filtration plant.
 George C. Earl, general superintendent, New Orleans sewerage
 and water board.
 Biscayne Engineering Co. of Miami, Fla.
 Dr. J. N. McGonigle, president, Miami Water Co.

CONDITIONS.

The conditions which existed when the Everglades Engineering Commission entered upon its duties as defined in the contract of April 30, 1913, are:

Lake Okeechobee, the great liquid heart of Florida, which, with the exception of Lake Michigan, is the largest body of fresh water wholly within the United States, lies at the focus of the greatest agricultural drainage problem in our country. This basin receives, to the limit of its capacity, the floods from a watershed 5,366 square miles in area. When that capacity is exceeded, the excess waters spill over its southern edge and flow southward over an area of 4,000 square miles known as the Florida Everglades, stretching away from the lake to the southern coast of the State. One canal, known as the Three-mile Canal, flowed westward into Caloosahatchee River; two canals had been dug through from the lake to waters discharging into the Atlantic, and a fourth was, and is, in process of construction. These canals are the South New River and Miami Canal, now designated as the Miami Canal and the North New River Canal. Through the full length of each canal there was a shallow navigation, but a large amount of rock has yet to be excavated from the Miami Canal to obtain the depth called for by the plans. These two canals were connected by a channel running east from the Miami Canal, which discharges into New River a short distance from where that stream receives the discharge of the North New River Canal. This east-west canal is now called the South New River Canal. The canal, then and now, in process of construction is known as the Hillsborough Canal. Though it has as yet no excavated outlet, it is discharging from Lake Okeechobee into the Everglades, about 400 cubic feet of water per second.

These canals, the initial part of a progressive drainage system, work on which is still progressing, under present conditions, even in so dry a season as that which has obtained for several months past, now serve to keep the Everglades wet because they are surcharged with Lake Okeechobee waters. This condition will not obtain when the whole project is carried out. The present canals will, as a part of a broad comprehensive system, be worth to the State every dollar that they have cost. They are there to serve a useful purpose in the great scheme of reclamation upon which the State has embarked; a scheme which has only to be carried to completion to make fertile fields of a watery waste and a populous land where now no man dwells.

PROGRESSIVE DRAINAGE.

We have encountered an idea, which if not generally prevailing is, at least, entertained by a large number of intelligent citizens of Florida to the effect that the problem of draining the Everglades can

not be solved by progressive steps, but that the whole area must forthwith be covered by a great interdependent system of canals. We believe this to be an erroneous idea, and that the Everglades can be reclaimed progressively, as is now planned by your board; that the work can so proceed as to reclaim the lands only as fast as there is need for those areas as homesteads and food producers. We regard Lake Okeechobee as the key to the solution of the whole problem. When that great reservoir is brought under control and the territory to the south is freed from the overflow of the lake, then the emancipated region can be relieved by adequate main drainage outlets and subsidiary canals whose capacities may be adjusted to meet the needs of the territory which they serve.

SURVEYS OF LAKE OKEECHOBEE, THE EVERGLADES, AND THE TERRITORY EMBRACED IN THE DRAINAGE DISTRICT ESTABLISHED BY ACT OF LEGISLATURE OF FLORIDA OF 1907, CHAPTER 5709.

Article 2 of the agreement between the board of drainage commissioners and Isham Randolph, engineer, provides that the Florida Everglades Engineering Commission shall procure and study all data, facts, information, and physical conditions affecting Lake Okeechobee, the Everglades, and all territory embraced in said drainage district, by personal reconnaissance of the territory embraced by Lake Okeechobee, the Everglades, and their watersheds.

Article 3 provides that the Florida Everglades Engineering Commission shall cause to be made such further surveys as may be necessary for its use in preparing recommendations for approximate location of canal routes and making the estimates of the cost of the construction of such works as they may recommend in said report.

Article 4 provides that the Florida Everglades Engineering Commission shall cause a map to be made of the area embraced within the scope of said investigations as nearly accurate as may be determined from the data, facts and information to be obtained, and shall show thereon, as far as may be by conventional signs, the ascertained facts and things to be done as recommended in said report, and the conventional signs shall be supplemented by such notes as may be appropriately entered upon said map.

Personal reconnaissance.—The Atlantic Coast Line from Detroit on the south to Stuart on the north, has been traversed by train, boat, automobile, horse, conveyance, and on foot and studied with all available data in hand. The Everglades themselves have been traversed via the Miami, North New River, and Hillsborough Canals.

Caloosahatchee River and the lakes and canals connecting it with Lake Okeechobee were examined as far west as Fort Myers, and Kissimmee River, from Kissimmee to Lake Okeechobee, was investigated.

Lake Okeechobee was accurately mapped for the commission and at its expense by the United States Geological Survey. This map is officially adopted by said Geological Survey, was searchingly studied and has formed the basis of many of our conclusions.

Particular investigation and study was made of the territory between Lake Okeechobee and along the Atlantic, north and south from Lake Worth to St. Lucie River.

Procurement of data.—In accordance with the terms of the agreement, the drainage board placed at the disposal of the commission

all data of which it was possessed bearing upon the matters covered by the investigation, in the form of maps, charts, printed or manuscript reports. Acknowledgment is here made of the willing assistance at all times rendered the commission by your board and its engineers.

In Appendix A (see p. 89) is a list of the maps, charts, etc., received from the drainage board from the Secretary of Agriculture, the superintendent of the United States Coast and Geodetic Survey, the Director of the United States Geological Survey, the Florida East Coast Railroad, the Everglades Land Sales Co., Prof. John T. Stewart of the University of Minnesota, formerly of the United States Department of Agriculture, and many others.

The district commissioners and this engineering commission must be considered especially fortunate in having been provided with so much information, much of which has never before been made public.

Surveys.—Realizing the prime necessity of prompt action, the engineer, immediately upon the execution of the agreement, organized two survey parties. One, the northern survey, under the direction of George B. Hills, carried a transit line, with levels, from the Atlantic Ocean to Lake Okeechobee, via Loxahatchee Slough. Through the faithful and intelligent efforts of the men of the party and their chief, this work was most successfully accomplished and physical difficulties were overcome which had previously frustrated all efforts in this direction. The work of this party was particularly valuable in locating the position of Lake Okeechobee with reference to the geodetic positions of the United States Coast and Geodetic Survey on the Gulf and Atlantic coasts, in furnishing a check upon the profiles developed farther north, and in establishing the most important negative fact that this locality was essentially not the right location for a control canal for Lake Okeechobee. The surveys of John T. Stewart, of the Department of Agriculture, and of the drainage board had already established the undesirability of a control canal from Lake Okeechobee to either Loxahatchee Slough or to Jupiter Inlet.

The second organization, the southern survey, consisted of two parties under the general supervision of J. B. Phinney, assisted by J. A. Moore. Its particular function was to establish the southern limit of the Everglades on the south, beyond which reclamation is at present impracticable on account of the prevalence of salt or brackish water. The main party ran a transit and level line from tidewater on the Atlantic at the east end of the Detroit Canal to tidewater on the Gulf of Mexico at the south of Hammer Key. The auxiliary party ran "offsets" at intervals north and south until satisfactory information was obtained concerning the limits of fresh and salt water in the south end of the Everglades.

When the northern and southern surveys had completed their allotted tasks, the southern crew was disbanded and Mr. Moore put in charge of the northern survey party and assigned to work on the west edge of the Everglades in the Big Cypress Swamp.

Accepting the location and elevations of the Department of Agriculture at Brown's store as correct, a transit and level line was run southwest to Chokoloskee Bay. The object of this survey was to define the territory tributary to the Everglades and to locate the drainage divide on the west. The information obtained was important, but entirely negative. It was found that the direction of drainage was indeterminate and variable, depending upon the height of

water, prevailing winds, density of growth on the prairies and in the channels, and other local conditions which changed with the seasons and the years.

The most important survey was that of Lake Okeechobee in cooperation with the United States Geological Survey, arranged for by Mr. M. O. Leighton. This survey, on a scale of 1 inch per 1 mile, was the work of E. P. Davis, topographer, United States Geological Survey. The resulting map shows the outlines of the lake and the 16 and 20 foot contours, above mean low water, Gulf of Mexico. This map is the first complete and accurate map of Lake Okeechobee. It shows the greatest lengths of the lake north and south to be 37 miles, east and west 31 miles, and the shore line of the lake, at the time of the survey, to be 135 miles. The area of the water surface at 20 feet above gulf is 730 square miles; at 19 feet it is 725 square miles; and at 16 feet, 710 square miles. The arrangement with the United States Geological Survey for cooperation was most satisfactory. It permitted the State to use the instruments and equipment of the Government as well as the skilled services of its expert engineers, the State paying only actual salaries and expenses. The resulting work carries all the prestige of Government for accuracy.

Cooperation, like that above mentioned, between the State and Government might advantageously be established for the following surveys, which the commission regards as essential before the definite plans for reclaiming the Everglades are put into effect:

First. A line of precise levels should be run from mean low water on the Gulf of Mexico to mean low water on the Atlantic Ocean, and geodetic control established along this line either by triangulation or by primary traverse. This survey is essentially a duty of the United States Government and your representatives in Washington should take immediate steps to have it made by either the Coast and Geodetic or the Geological Survey, both of which organizations are equipped with men and instruments for such surveys.

Second. A topographic map on a scale of 1 mile to 1 inch with contour intervals of $2\frac{1}{2}$ and 5 feet should be made from Stuart southwest to the east shore of Lake Okeechobee, covering all territory through which it might be possible to construct the control canal. This work could be done in cooperation with the United States Geological Survey, but in consideration of its pressing necessity and the fact that the territory to be mapped does not correspond to the latitude and longitude boundaries of Geological Survey atlas sheets, it would appear best for it to be immediately undertaken by other agents. Simultaneously, borings should be made to establish soil conditions over the several alternate routes of the control canal.

Third. A hydrographic chart of the St. Lucie River, showing shore outlines and depths of water from the inlet to the head of South River should be made, in cooperation with either the Coast and Geodetic Survey or the Hydrographic Office.

Appendix B (see p. 90) is a list of tide gauges upon the Atlantic and Gulf coasts as furnished by the United States Coast and Geodetic Survey.

Appendix C (see p. 103) is a list of bench marks of the Florida Coast Line Canal as furnished by the United States Army Engineers. These tide gages and bench marks should be connected by level lines.

Maps.—In addition to the map of Lake Okeechobee, made in cooperation with the United States Geological Survey, the commission has caused to be compiled two maps, viz:

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1. *Florida, south of latitude 28° 30'.*—A polyconic projection was constructed for the parallels 24° 30' to 28° 30' and meridians 80° to 83° on a scale of 1:380,160 (6 miles=1 inch) showing the meridians and parallels at intervals of 30', using for the construction of this projection the tables of the United States Coast and Geodetic Survey. Upon this projection was transferred Coast and Geodetic charts Nos. 162 to 167, inclusive, and 173 to 178, inclusive, so that the exterior parts of the territory mapped are accurately located, but only these parts. Within these meridians was compiled the information carried on the latest maps of the General Land Office, the Post Office Route Map, the United States Geological Survey map of Florida, the United States Army Engineer charts, and other maps of the area under investigation, giving to each map such weight as its proved accuracy justified, so that the resulting map is as nearly accurate as may be determined from the available data. It must at all times be understood that information does not exist for the making of a map geodetically correct.

On this map are shown, by conventional signs, the ascertained facts and a general plan of works recommended in this report. These works are also shown in detail by conventional signs on the second map, which is:

2. *Lake Okeechobee section—Florida Everglades.*—This map is constructed on a scale of 1:63,360 (1 mile=1 inch), and includes the area between parallels 26° 33' N. to 27° 20' N., and meridians 80° W. to 81° 10' W., showing the meridians and parallels at intervals of 10 feet. On it is placed all information contained on the map previously described and such additional data as this larger scale permits, the same sources of information being used. On prints of this map are shown in detail the things recommended in this report. The conventional signs of the map are supplemented by approximate notes entered thereon. These details are entered on separate prints instead of the original maps because it is expected that the latter will serve as a base or mother map from which prints may be made for future uses.

CANALS.

Article 3 of the contract provides that "such canals and works incident or necessary thereto to be shown on said plans * * * shall be sufficient in number and capacity to provide the system of main canals required to drain the land area embraced within said drainage district, so far as the same may be accomplished without resorting to pumping the water from the land and that will be sufficient to relieve the land aforesaid of all surface water, but the said report shall not deal particularly with minor subdivisions of land. Farm ditches are not to come within the purview or scope of said report."

Main canals are defined as being the canals carrying the water of the drainage district and its watershed to some major body of water.

MAIN CANALS.

At present there have been excavated as main canals the North New River, South New River, and Miami Canals. Those under construction are the Cypress Creek, Snake Creek, Snapper Creek, and Hillsborough Canals. Contract has been let for the West Palm Beach Canal.

Until completed as planned this system of main canals will not wholly accomplish the purpose of reclamation, but after the construction of the Lake Okeechobee-St. Lucie Canal it will not be unreasonably expensive to so increase its capacity that it will suitably drain a major portion of the drainage district.

The existing system of canals contemplates the reclamation of a greater portion of the Everglades in the immediate future than will probably be justified by the demand for new lands. It would have been much better to provide for an orderly progression of reclamation in accordance with the demand and with due regard to market conditions and transportation facilities. The existing works and the conditions of land, ownership and settlement, seems now to be such as to necessitate an earnest effort to reclaim in one continuous project and with the greatest possible expedition all the lands south and southeast of Lake Okeechobee, between the Miami Canal, the proposed West Palm Beach Canal, and the eastern boundary of the drainage district.

Moved by these considerations, the commission has endeavored to plan such a system as will permit the State to provide adequate main canal drainage for this territory.

The larger project may naturally be divided as follows:

1. Between south shore of Lake Okeechobee-Miami Canal, Hillsborough Canal, and eastern boundary of drainage district.
2. Between Miami and Detroit.
3. Allapattah Flats, in northeast portion of drainage district.
4. In northwest corner drainage district, beyond Lake Okeechobee.
5. South and west of the Miami Canal, to the south and west boundaries of the district.

The proposed scheme provides—

(a) That the drainage capacity of the Hillsborough Canal be supplemented by the construction of the canal marked VIII on the map, beginning at a point midway between the West Palm Beach Canal, and the Hillsborough Canal about 10 miles from Lake Okeechobee and running southeast about 33 miles to the Hillsborough Canal at the eastern edge of the district. The final capacity of this canal should be sufficient to reclaim 340 square miles.

(b) That from a point midway between the Hillsborough Canal and the North New River Canal about 9 miles southeast of Lake Okeechobee, a canal marked IX on the map shall be constructed southeast, emptying into the Cypress Creek Canal enlarged, a total length of 32 miles, designed to drain 240 square miles.

(c) That from a point midway between the Miami Canal and the North New River Canal about 25 miles south of Lake Okeechobee a canal marked X on the map shall be constructed southeast, crossing the South New River Canal, to connect with the present Snake Creek Canal. This canal must be designed to drain 429 square miles.

(d) The present Snake Creek must be enlarged from this point of connection to the Atlantic Ocean to carry the drainage from a territory of over 400 square miles.

(e) When the foregoing canals have been constructed, those already in existence or contracted for will have the following duties imposed upon them: The Miami Canal, from the lock 9.1 miles south of Lake Okeechobee to the Miami River will drain an area 1.5 miles on either side, a total area of 216 square miles. The North New River Canal, from the lock 8.75 miles south of Lake Okeechobee to New River

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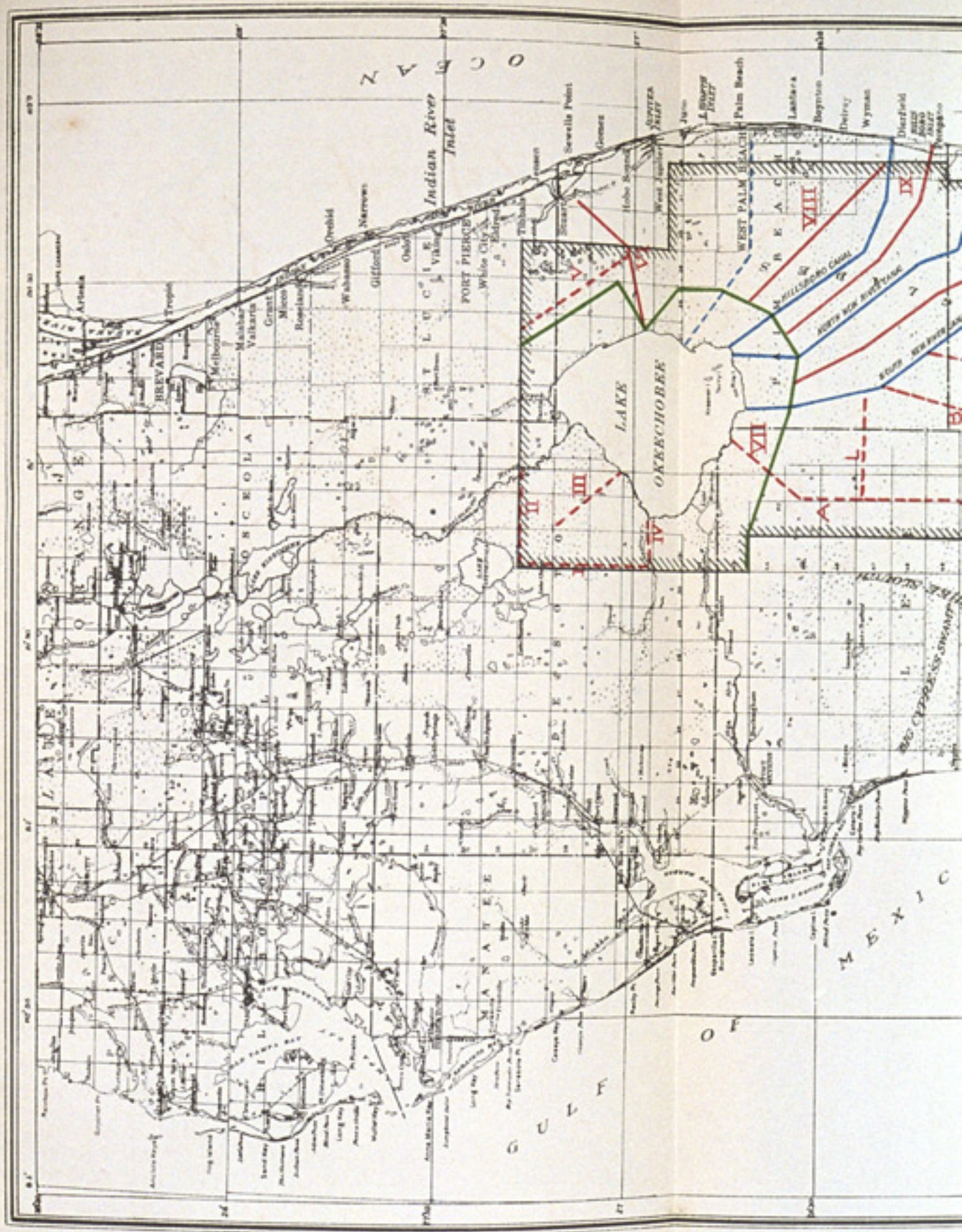
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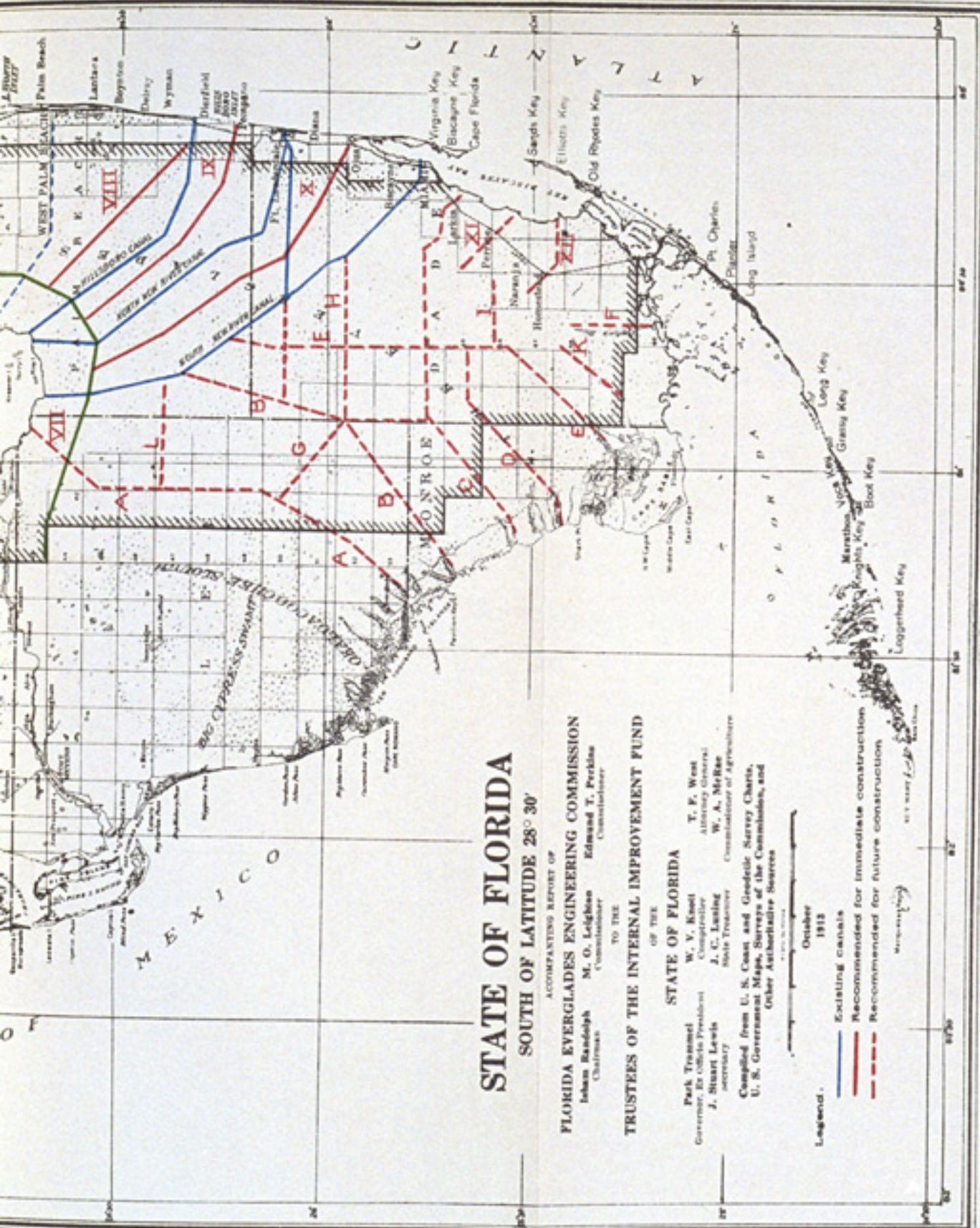
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ACCOMPANYING REPORT OF
FLORIDA EVERGLADES ENGINEERING COMMISSION
 John Randolph Chairman
 M. O. Leighton Commissioner
 Edmund T. Perkins Commissioner




TO THE
TRUSTEES OF THE INTERNAL IMPROVEMENT FUND
 OF THE

STATE OF FLORIDA

Park Trammel Governor
 J. Stuart Lewis Secretary
 W. V. Kneel Comptroller
 J. C. Lansing State Treasurer
 T. F. West Attorney General
 W. A. McRae Commissioner of Agriculture

Compiled from U. S. Coast and Geodetic Survey Charts,
 U. S. Government Maps, Surveys of the Commission, and
 Other Authoritative Sources

October 1913

- Legend.**
-  Existing canals
 -  Recommended for immediate construction
 -  Recommended for future construction

will drain an area of 190 square miles. The Hillsborough Canal, from the lock 12 miles southeast of Lake Okeechobee, will drain 186 square miles. Cypress Creek Canal must be enlarged to carry the drainage of 240 square miles.

By reason of the above-mentioned locks and the construction of the canal marked "VII" on the map, there is turned into Lake Okeechobee from the south and east the drainage of 500 square miles. Canal VII will be constructed from the west center line of township 44 south, range 33 east, in a northeasterly direction 12 miles to Lake Okeechobee, and is designed to drain 106 square miles of territory.

(f) From Miami to Detroit there is a strip of land, approximately 10 to 12 miles wide, tributary to the Atlantic Ocean. For main canals in this territory it is believed that the present Snapper Creek Canal, with the construction of canals marked "XI" and "XII" on the map, will suffice. Canal XI extends from about the center of township 55 south, range 39 east, in a southwesterly direction 10 miles into Biscayne Bay, draining 65 square miles. Canal XII extends from the south center of township 56 south, range 38 east, in a southwesterly direction 7.5 miles to the Detroit Canal, draining 72 square miles. The Detroit Canal is private property, but arrangements should be made by the State to acquire it and enlarge it to complete canal XII to Biscayne Bay. Provision is made for extending Snapper Creek Canal to the west across the Everglades to the west center of township 54 south, range 35 east, as a part of the progressive development of the future.

(g) The Allapattah Flats in the northeast corner of the drainage district are to be drained by a canal marked "V" on the map, running from the northern edge of the drainage district in township 37 south, range 38 east, in a southeasterly direction 23.5 miles to the Okeechobee-St. Lucie Canal, designated "VI" on the map. Canal V is designed to drain 195 square miles; canal VI is designed not only to carry a minimum of 5,000 second feet of water for control of water level in Lake Okeechobee and for power purposes, but also the drainage of canal V, which will drain 75 square miles.

(h) The northwest corner of the drainage district beyond Lake Okeechobee presents an isolated problem and is, in itself, an illustration of the fact that it is possible to economically drain fractional portions of the Everglades. Canal I, beginning in the northwest corner of the drainage district and running due south 24 miles to Fisheating Creek, is designed to drain 50 square miles of territory. The spoil from this excavation should all be deposited in the form of a levee on the west. This levee and the canal itself will prevent overflow from the lands west of the district. Canal II, projected from the northwest corner of the drainage district, due east 16 miles into the Kissimmee River, and is designed to drain 49 square miles. It will also protect the lands of the district from overflow from the north. Canal III, running from the southeast corner of township 37 south, range 31 east, 14.5 miles to the shore of Lake Okeechobee, is designed to drain 200 square miles. Canal IV provides for a canalization of Fisheating Creek for 9.5 miles and is designed to carry the water of 740 square miles of territory.

(i) In the future, as the lands in parts 1 and 2 are reclaimed, settled, and cultivated, it will be necessary to extend the canal system to the west and south, and suggestions, of course, which take advantage of

all information obtainable as to the elevations and natural channels, are here made. It is impossible now to determine precisely the most advantageous method of making such extensions, for this will be dependent upon the settlement and development of the areas first reclaimed.

It is suggested that the canal A in the western part of the district might start at the lock at the end of canal VII and continue southwest of the line between ranges 32-33 east, thence south past Glade Cross Mission and the Seminole Indian Reservation and across the eastern branch of Okaloacoochee Slough to the headwaters of Turner River and down Turner River to Chokoloskee Bay. Such a course will protect the west edge of the drainage district from overflow from the Big Cypress Swamp, and form a direct and short connection from Lake Okeechobee to the Gulf.

Canal B should be constructed from a point on the Miami Canal about 25 miles south of the lake, thence south of west to the west center of township 52 south, range 35 east, thence to Chatham River.

Canal C should start from canal B in the west center of township 52 south, range 35 east, and run south 12 miles, thence southwest to Lossman River.

Canal D begins at canal E in the southeast corner of township 55 south, range 36 east, and extends 8.5 miles west, thence southwest to the inlet from the Gulf of Mexico.

Canal E should run south from the junction of Miami Canal in township 49 south, range 37 east, to southeast corner of township 56 south, range 36 east, thence southwest into White Water Bay.

Canal F begins east of Royal Palm Key and runs approximately south into Taylor River.

Canal G is designed to connect canals A and B through the eastern branch of Okaloacoochee Slough.

Canal H should extend east from junction of canals B and C at west center of township 58 south, range 35 east, to the Miami Canal.

Canal I runs east 11 miles from east center of township 56 south, range 36 east.

Canal K is planned to extend southwest from south shore of Royal Palm Key to salt water, about the east center of township 59 south, range 55 east.

Canal L runs east and west between Miami Canal and canal A in the north part of township 47 south.

The South New River Canal is to be extended west to reach canal B.

Snapper Creek Canal is to be enlarged and extended west to reach canal C. It is believed that the system of main canals above traced will be sufficient to reclaim this part of the drainage district; but where this extension will begin will be dependent upon conditions as they develop.

ESTIMATE OF COST.

Assuming $n=0.035$; side slope 1:1; $s=0.3$ foot per mile $=0.00057$ and the water surface 3 feet below present ground surface, the total quantities and costs in thousands for the various parts of the project are as follows for 0.6 inch run-off per day:

1. BETWEEN SOUTH SHORE OF LAKE OKEECHOBEE, MIAMI CANAL, HILLSBOROUGH CANAL, AND EASTERN BOUNDARY OF DRAINAGE DISTRICT.

(A) ADDITIONAL CANALS.

Canals.	Length.		Cubic yards excavation.	Unit cost.	Total cost.
	Miles.	Sq. mi.			
VIII.....	33.00	349	7,078,000	9	\$637,000
IX.....	42.00	242	7,844,000	10	784,000
X.....	61.00	429	15,510,000	10	1,551,000
Total.....	136.00	1,011	30,432,000		2,972,000

(B) ENLARGEMENTS, PRESENT CANALS SOUTH OF PROPOSED LOCKS.

West Palm Beach.....	32.00	96	(1)		
Hillsborough.....	38.00	186	500,000	12½	
North New River.....	47.00	190	1,800,000	12½	
South New River.....	24.00	72	1,450,000	12½	
Miami.....	72.00	216	4,650,000	12½	
Total.....	213.00	760	8,400,000		\$1,000,000

(C) ENLARGEMENTS, PRESENT CANALS NORTH OF PROPOSED LOCKS.

West Palm Beach.....	12.00	69	(1)		
Hillsborough.....	12.00	59	795,000	10	
North New River.....	8.75	105	344,000	10	
South New River.....	9.1	91	433,000	10	
Total.....	41.85	324	1,572,000		\$157,300

¹ Sufficient as at present designed.

(d) Four standard locks, at \$25,350, \$101,400.

A grand total of 390 miles of canal, draining 2,095 square miles, or 1,341,000 acres, at a total cost of \$4,281,000, or \$3.20 above present expenditures.

To this cost per acre must be added the cost per acre to the entire district for one-third of the expenditures on the Lake Okeechobee-St. Lucie Canal, which is as follows:

Excavation for canal.....	\$2,182,990
Locks.....	48,000
Dam.....	18,467
Excavation for locks and dam.....	9,014
	2,258,471

or 22 cents for each of the 3,372,000 acres of the drainage district benefited by this canal. The acreage benefited is estimated by deducting from the 4,000,000 acres of the district 464,000 acres, the surface of Lake Okeechobee at elevation 19, and 164,000 acres between Miami and Detroit, which this canal does not affect.

Canal VII is just west of this territory. Its 12-mile length drains 106 square miles of territory, or 68,000 acres, with an excavation of 2,500,000 cubic yards of muck, estimated to cost \$150,000, or \$2.20 per acre, a total of \$2.76, including Lake Okeechobee-St. Lucie Canal,

2. BETWEEN MIAMI AND DETROIT.

Canals.	Length.	Area drained.	Cubic yards excavation.	Unit cost.	Total cost.
	<i>Miles.</i>	<i>Sq. miles.</i>		<i>Cents.</i>	
XI.....	10.00	63	1,656,000	12½	.....
XII.....	7.50	72	1,468,000	12½	.....
Detroit.....	9.00	108	1,616,000	12½	.....
Snapper Creek.....	6.00	13	160,000	12½	.....
	32.50	256	4,900,000	.....	\$613,000

or 164,000 acres, at a cost of \$3.70 per acre for main canals.

3. ALLAPATTAH FLATS IN NORTHEAST PORTION OF DRAINAGE DISTRICT.

Canal V is 23.5 miles long, drains 195 square miles of territory, with an excavation of 6,188,000 cubic yards of muck, estimated to cost \$372,000, or for 125,000 acres \$2.95 per acre, a total of \$3.51 per acre,

4. NORTHWEST CORNER DRAINAGE DISTRICT BEYOND LAKE OKEECHOBEE.

Canals.	Length.	Area drained.	Cubic yards excavation.	Unit cost.	Total cost.
	<i>Miles.</i>	<i>Sq. miles.</i>		<i>Cents.</i>	
I.....	24.00	50	2,565,000	6	.....
II.....	16.00	49	1,625,000	6	.....
III.....	14.50	197	3,704,000	6	.....
IV.....	9.50	(740)	4,013,000	6	.....
	63.00	296	11,907,000	.....	\$714,420

or 192,000 acres, at a cost of \$3.71 per acre, a total of \$4.27.

These computations make the cost per acre above present obligations \$3.64 for 1,890,000 acres, and for the remaining district as follows:

5. SOUTHERN AND WESTERN PORTIONS OF DRAINAGE DISTRICT.

Canals.	Length.	Area drained.	Cubic yards excavation.	Unit cost.	Total cost.
	<i>Miles.</i>	<i>Sq. mi.</i>		<i>Cents.</i>	
A.....	62.0	673	20,090,000	20	\$4,018,000
B.....	55.0	555	20,651,000	20	4,130,200
C.....	32.0	316	7,447,000	20	1,489,400
D.....	31.0	252	3,788,000	20	757,600
E.....	27.0	175	5,274,000	20	1,054,800
F.....	8.5	120	1,316,000	20	263,200
G.....	17.5	126	2,710,000	20	542,000
H.....	21.0	106	1,205,000	20	241,000
I.....	9.0	88	971,000	20	194,200
J.....	9.0	66	896,000	20	173,200
K.....	18.0	209	2,858,000	20	571,600
L.....	17.0	63	1,636,000	20	327,200
South New River.....	27.0	158	4,336,000	20	867,200
Snapper Creek.....					
Total.....		2,907	73,148,000	.....	14,635,600

approximately 1,900,000 acres, of which 400,000 lie without the district, at a cost per acre for main canals, \$7.70, or a total cost, including pro rata of Lake Okeechobee-St. Lucie Canal, of \$7.92.

RAINFALL IN THE EVERGLADES.

Plans for drainage of the Everglades will largely be determined according to the amount of rainfall that occurs over that region. Therefore, a close study of existing data is advisable. Within the Everglades no long-term precipitation records are available. Some stations have recently been established therein by this commission and by other official and private parties, but the terms of observation are not long enough to afford any useful data. Immediately after this commission began its work, rainfall stations were established at the following points: Detroit, Miami Canal, at Barkley's (about 8 miles above Miami), North New River Canal at Dredge Everglades (30 miles above Fort Lauderdale), Lake Okeechobee at head of North New River Canal, and Okeechobee Town on Taylors Creek, a few miles north of the lake. In addition to these interior stations, others have been maintained for short periods, viz: South New River Canal at Zona, North New River Canal at the lock (about 8 miles above Fort Lauderdale), Lake Okeechobee at Rita, Fla. (head of Miami Canal), and on Observation Island. During the maintenance of these stations, with the exception of the one last mentioned, no large general storms have been recorded. The records consist principally of local shower catchments. Therefore, they are almost valueless for the purposes of this report. The observations will, however, be hereinafter set down for purposes of record.

Records of rainfall at two or more points on or near the rim of the Everglades have been made since 1888. The location of these places are shown on the accompanying sketch map. During the past 14 years the Everglades have been well surrounded by observation stations. They may be classified as follows: Northern stations—Clermont, Kissimmee, and Orlando. Atlantic coast stations—Malabar, Fort Pierce, Jupiter, Hypoluxo, and Miami. Southern station—Fleming. Western stations—Marco, Fort Myers, Arcadia, and Avon Park. Other stations on or near the Everglades rim, such as Bartow and Fort Meade have recently been established, but the term of record is too short to permit of valuable application here. Record of precipitation by months at the above-mentioned long-term stations is given in Table No. 1. (See pp. 19-22.)

Record of daily precipitation from May to September, inclusive, 1913, is set forth in Table No. 2. (See pp. 23-31.)

The figures set down in Table No. 1 represent the total and the average monthly and yearly precipitation at the several places of observation. In the plans originally adopted by the State for Everglades drainage, these average results largely formed the basis of conclusion as to the necessary capacity and number of drainage outlets. Therein lies in large part the cause of certain erroneous deductions that were then made.

It is clear that if a monthly rainfall of, say, 6 inches were distributed uniformly throughout one month, a comparatively small outlet capacity would suffice to carry all run-off water. If, on the

other hand, the monthly rainfall of 6 inches occurred in one day, a serious flood would occur unless the outlet capacity were large. Therefore, in adjusting the proposed drainage canals in any swamp area, storm units rather than average monthly units must be used.

Study must also be given to the probable relative distribution of the storm precipitation. In order to have full information at hand and to conveniently study relative distribution, Table No. 3 has been prepared. It expresses the total catchment at the several points of observation of all the large storms that have occurred from 1899 to 1912, inclusive; also many of the smaller storms which were general in their extent. It has occasionally occurred that a general storm has persisted over the entire month or has been so nearly continuous that it is impossible to separate the several storm units. In such cases the entire month's record has been entered in the table. (See Table No. 3, pp. 32-34.)

Station
1901
Jupiter
Fort Myers
Minn.
1902
Jupiter
Fort Myers
Minn.
1903
Jupiter
Fort Myers
Minn.
1904
Jupiter
Fort Myers
Minn.
1905
Jupiter
Fort Myers
Minn.
1906
Jupiter
Fort Myers
Minn.
1907
Jupiter
Fort Myers
Minn.
1908
Jupiter
Fort Myers
Minn.
1909
Jupiter
Fort Myers
Minn.
1910
Jupiter
Fort Myers
Minn.
1911
Jupiter
Fort Myers
Minn.
1912
Jupiter
Fort Myers
Minn.