REPORT ON THE DRAINAGE OF THE EVERGLADES OF FLORIDA, BY J. O. WRIGHT, SUPERVISING DRAINAGE ENGINEER.

[Prepared under the direction of C. G. Elliott, Chief of Drainage Investigations.]

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., June 25, 1909.

SIR: I have the honor to transmit herewith a report on the drainage of the Everglades of Florida, prepared from examinations and surveys made by John T. Stewart and Lawrence Brett, drainage engineers, under the general direction of J. O. Wright, supervising drainage engineer of this office.

The field examinations were made during the winters of 1906–7 and 1907–8 at the request of the Board of Trustees of the Internal Improvement Fund of the State of Florida, for the purpose of ascertaining the practicability of draining the Everglades and making them profitable for agriculture. The Trustees cooperated by placing at the disposal of this office all data which had been collected by the board relating to the lands which were examined, and furnishing a boat and a man to manage it in making the examination of Lake Okeechobee.

The report proposes a plan for draining the land and discusses its probable value for agriculture. In view of the public interest now shown in the reclamation of wet and swamp lands throughout the country, I recommend that the report be published as a bulletin of this office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

INTRODUCTION.

Since the discovery of Florida by Ponce de Leon in 1513 much interest has from time to time been manifested in the southern part of the peninsula. It has been the field of national strife and its history discloses a series of interesting and exciting events. Both the British and Spanish Governments long regarded it as a land of inestimable wealth, occupying a highly stragetic position. In the endeavor of European nations to secure and hold this coveted treasure it became the theater of war and bloodshed. Prior to its acquisition by the United States it twice changed ownership, inhabitants, and policies, and was regarded as the legitimate prey of unscrupulous rovers of the sea and fortune seekers of the Old World.

When finally acquired by the United States, the southern part became a refuge for the Seminole Indians, whom the Government failed to entirely remove or subdue. Under such conditions any material development of its natural resources could not be expected. During this early period the information pertaining to the interior of the country, particularly the Everglades, was more fanciful than real. Its fertility and possibilities were extolled by those who ventured beyond the settlements along the coast, but reliable geographic and scientific data were entirely lacking.

EARLY DESCRIPTIONS OF THE EVERGLADES.

That portion of the peninsula lying south of Lake Okeechobee, called by the Indians "Pah-hah-okee" or "Grassy Water," is commonly known as "the Everglades." It has never been surveyed by the United States Land Office, but is designated on the maps by those who surveyed the adjacent lands as an impenetrable marsh. In the school geographies it is described as "An extensive muck swamp covered with a dense saw grass, evergreen pines, and palmettos, and dotted here and there with wooded islets. It is the favorite haunt of aquatic birds, alligators, and numerous snakes and other reptiles." This description of the Everglades is commonly accepted throughout the country.

The first authentic information concerning this part of Florida was gathered during the Seminole War by the United States Army officers, who made extended explorations in small boats during the periods of high water, and transmitted quite full descriptions of the country to the Secretary of War.

On June 18, 1847, Hon. J. R. Walker, Secretary of the Treasury, appointed Buckingham Smith, of St. Augustine, Fla., to make an examination and report on the Everglades. The scope and character of the work intrusted to this gentleman can best be shown by extracts from the letter of instructions issued to him. (See p. 37.)

> It has been reported to the department that there are several thousand acres of public lands in the vast lake called "the Everglades," which can be reclaimed and rendered valuable at an expense comparatively small with the advantages resulting from such measure. It is reported that these lands can be drained by two or three small canals, from the lake into the river opposite to it, emptying into the Gulf of Mexico and into the Straits of Florida. This department is not in possession of any official information in relation to them which would justify its recommendation of such a measure, but the opinion is entertained, from the representations made, that the measure is not only practicable, but would be beneficial to the public interests. The department relies upon you to procure and furnish in your report full information on this subject. * * * You will examine personally, if you can, the region where the proposed cuts will have to be made. State its character, geological formation, the probable length, breadth, and depth of the proposed cuts or canals, the probable excavation necessary, and also the character and anticipated expense and results of the work sought to be undertaken. Any information you can obtain in writing from intelligent citizens acquainted with the subject you will communicate with your report. And you will cull from these facts specific data showing the correctness of the opinions given. Congress and the department must look to you to justify action on this subject.

On June 1 of the following year Mr. Smith made an extended and comprehensive report of his investigations and submitted numerous papers and letters to support such conclusions as he saw fit to submit. The report is too long to be inserted here, but anyone interested can

find it in Senate Report No. 242, Thirtieth Congress, first session. (See p. 46.) With reference to draining the Everglades, he says:

To reclaim the Everglades, Okeechobee must be tapped by canals running into the Caloosahatchee on the one side and the Loxahatchee or St. Lucie, or both, on the other, and cuts must also be made from the streams on both sides of the peninsula into the Glades. Besides, after the height of water in the Glades shall be decreased, even as much as 5 feet, there will probably be a necessity for several drains through the Glades, by which the waters accumulating from the rains may be conducted to the ocean or Gulf.

A later description of the Everglades appeared in a memoir published in 1856 to accompany a military map known as the "Davis map." (See p. 71.) The name of the writer does not appear, but his description is so accurate and clear that it is here reproduced:

The Everglades of Florida cover an area of about 4,000 square miles, embracing more than one-half of the portion of the State south of Lake Okeechobee. The subsoil of this vast region is coralline limestone. Upon the surface of this, which is very rough and irregular, lies an immense accumulation of sand, alluvial deposits, and decayed vegetable matter, forming a mass of quicksand and soft mud, from 3 to 10 feet or more in depth, that overspreads all but a few points of the first stratum. Upon the mud rests a sheet of water, the depth varying with the conformation of the bottom, but seldom, at dry seasons, greater than 3 feet. The whole is filled with a rank growth of coarse and tough grass from 8 to 10 feet high, having a sharp edge like a saw, from which it obtains its name of saw grass. In many portions of the Everglades this saw grass is so thick as to be impenetrable, but is intersected by numerous narrow and tortuous channels that form a kind of labyrinth where outlets present themselves in every direction, most of them, however, terminating at longer or shorter distances in an impassable barrier of grass, mud, and quicksand. The surface water is quickly affected by rains, the alternate rising and falling during the wet seasons being very rapid. The difference of level between the highest and lowest stages of water is from 2 to 3 feet. The general surface of the Everglades is therefore subject to great changes, the character of marshy lake or mud flat predominating according to the wetness or dryness of the season. It is probable that sometimes more than one-half of the surface has no water upon it. Besides the mud islands small keys are here and there met with, which are dry at all seasons. Upon these the soil is very rich. There are many such, undoubtedly, that are often made the sites of Indian gardens. In some places they will be grown up with bushes, appearing in the distance like a continuous wood, and occasionally there are clumps of pine, cabbage palmetto, cypress, and live oak.

THEORY OF THE FORMATION OF THE EVERGLADES.

At one time it was taught by geologists that the southern part of Florida was of coral origin, but recent examinations lead them to believe that its formation is similar to that of the coast of Georgia and South Carolina, and belongs to the "post-Pliocene age." The present surface rests on a bed of oolitic limestone, embedded with sand and shells. The underlying rock is nearly horizontal, dipping slightly toward the south, but does not denote any sudden upheaval. Its surface is irregular, being full of potholes, deep fissures, varied by irregular and jagged ridges and seams. It is not stratified, but is homogeneous in character, and is rotten or porous and susceptible of being easily excavated. In places it is quite retentive of moisture, but hardens when exposed to the air and makes a good surface for roads. This rock foundation underlying the entire southern part of the peninsula was at one time the bed of an inland sea. Along the eastern edge, parallel with the Atlantic coast, is a rock rim, or barrier, from 3 to 5 miles wide, that rises at the north end, opposite Lake Okeechobee, 10 or 12 feet higher than the bedrock in the center of the Glades, opposite this point. As this ridge extends south its elevation

gradually approaches the level of the bedrock, and at the mouth of the Miami River it has but a slight elevation above the level of the interior of the basin. South of Miami the ridge diappears, and the entire peninsula from the Atlantic to the Gulf coast is a rocky surface, dipping slightly toward the south and west. On the west coast there is a rock rim wider than on the east coast, but not so high. The backbone of the ridge is found at Fort Thompson, about 20 miles west of Lake Okeechobee, and extends in a southerly direction, almost parallel with the rim on the east coast; it gradually decreases in elevation until it is finally lost by merging into the bedrock at a point about west from Miami. The area inclosed by these rock rims, lying south of Lake Okeechobee, is about 90 miles long and 40 miles wide, and constitutes what is, strictly speaking, the Everglades. People who live in that locality, however, are accustomed to speak of any large marshy territory covered with grass as a part of the Everglades, whether it is within the inclosure formed by these rock rims or not.

There is no doubt that at one time this basin was an open sea, but by the action of the wind and waves, sands and particles of stone were carried in and deposited, until the water was sufficiently shallow for plant life to exist. Aquatic plants then sprang up, and by constant accretions through a succession of years the entire basin has been filled to the level of the marginal rims with a deposit of sand and muck, so that the surface of the Everglades is now a plane with a gentle slope from the north to the south.

NATURAL DRAINAGE.

During this formative period water that was discharged by the Kissimmee River into Lake Okeechobee while endeavoring to find an outlet to the sea broke through the rock rim in many places, both on the east and the west coast, and by its constant action eroded the rock, so that there are numerous channels through which the surface water now flows quite freely from the Everglades, both into the Atlantic Ocean and the Gulf of Mexico. In many places these channels are worn down several feet deep, but do not extend far beyond the rim into the interior. The water is brought from the margin of the Glades in small rivulets to the heads of these streams, which increase in size as they approach the outlets. The difference in elevation between sea level and the source of these streams gives many of them sufficient fall to cut out large and deep channels. The streams on the east coast, beginning at Rock Ledge and going south, are as follows: Sebastian River, St. Lucie River, Loxahatchee River, Hillsboro River, Cypress Creek, New River, Snake Creek, Arch Creek, Little River, and Miami River. These streams are shorter and have more fall per mile than those on the west coast. None of them are connected directly with Lake Okeechobee, although they receive more or less water from it during the period of heavy rains. On the west coast the conditions are somewhat different.

The Caloosahatchee River, a stream of considerable importance, takes its water directly from Lake Okeechobee and the adjacent country on the west, and flows southwest to Fort Myers. Along the upper part of its course it passes through some canals that were constructed by the Disston Co. 18 years ago, and thence through Bonnet

Lake and Lake Flirt, which are large marshy areas that are covered with water 4 or 5 feet deep during the rainy season, but are practically dry the remainder of the year. From Lake Flirt to Fort Denaud the channel passes through the rock rim, which is harder than the stone found on the east side. The action of the water is quite slow in cutting away this rim, and some work has been done by interested parties in widening and deepening this portion of the channel to improve navigation. South from Fort Myers the Gulf coast is not well defined, but is low and characterized by numerous indentations filled with mud flats and little islands called "keys," which are overgrown with mangrove. Many of these inlets extend several miles into the land, but they are so tortuous in their course and so thickly covered with mangrove that they are difficult to follow. The tide ebbs and flows in and out among these keys and extends many miles inland, forming a vast swamp. Much of the drainage from Lake Okeechobee and the west side of the Everglades finds its way slowly through the dense growth of saw grass to the south and west, and finally empties into this vast mangrove swamp. There are not so many streams on the west as on the east coast, the principal ones being the Caloosahatchee, Harneys, and Shark Rivers.

TEMPERATURE.

Highly favorable conditions in regard to temperature obtain in that portion of Florida south of Lake Okeechobee. Frosts are of rare occurrence, and when they do occur usually cause but little injury.

The following tables, compiled from the records of the United States Weather Bureau, give the mean annual temperature and the highest and lowest temperatures at Jupiter and Fort Myers for a period of nine years:

Mean annual, highest, and lowest temperatures at Jupiter and Fort Myers, 1898–1906.

Years.	Jupiter.			Fort Myers.		
	Annual mean temperature.	Highest during the year.	Lowest during the year.	Annual mean temperature.	Highest during the year.	Lowest during the year.
	°F.	°F.	°F.	°F.	°F.	°F.
1898	73.7	91	31	72.6	94	28
1899	74.4	93	28	73.1	93	28
1900	74.3	93	31	72.3	92	34
1901	72.6	92	38	70.3	94	32
1902	74.4	96	38	72.2	94	31
1903	74.1	96	36	71.8	94	35
1904	73.8	94	39	.....	94	34
1905	74.6	94	24	73.5	94	27
1906	73.7	91	30	72.4	92	31

These stations are both north of the main body of the Everglades, and no doubt show from 2° to 4° lower temperature than would be registered in the center of the Glades. The minimum temperature here is higher than that of the sugar district in Louisiana south of New Orleans, where cane is seldom injured by frost. On account of this immunity from cold, sugar cane has a longer season in which

to grow and ripen, and is consequently much richer in sucrose. The grinding operation need not be commenced before the cane is fully matured, which greatly increases the yield of sugar per acre. Although light frosts have been known occasionally to injure more delicate plants, yet sugar cane and the hardy vegetables, as cabbage and potatoes, grow in the open field all winter.

The summers in this district are not as hot as one would naturally expect from its latitude. During the period 1898 to 1906 the maximum temperature at Jupiter was 96° F. and at Fort Myers 94° F., which is less than that of Minnesota or North Dakota during the same period. The summer weather in southern Florida is usually attended with a sea breeze of 4 to 8 miles per hour, which makes it quite pleasant in the shade. At night this breeze increases, so there is little discomfort from the heat.

The following table gives the mean daily temperature, velocity of the wind, and the relative humidity of the atmosphere for the months of July and August, 1905, at Jupiter:

Weather conditions for July and August, 1905.

Days of month.	Mean daily temperature.				Velocity of wind per hour.		Relative humidity.	
	Kissimmee.		Jupiter.		Jupiter.		Jupiter.	
	July.	August.	July.	August.	July.	August.	July.	August.
	°F.	°F.	°F.	°F.	Miles.	Miles.	Per ct.	Per ct.
1	80	79	82	84	3.0	9.5	85	83
2	81	79	82	80	4.5	5.0	84	92
3	82	78	84	78	6.0	9.0	83	89
4	82	79	84	83	9.0	8.0	87	84
5	81	76	82	84	5.5	7.5	86	83
6	76	81	81	80	8.5	3.5	76	85
7	80	81	80	78	9.0	4.0	84	83
8	80	80	81	81	10.0	10.0	80	74
9	80	81	80	84	6.0	10.0	90	78
10	80	83	80	83	6.5	6.5	80	82
11	80	82	80	81	8.5	5.5	83	84
12	[1] 72	82	80	82	6.0	8.5	87	84
13	[1] 71	82	76	82	7.5	17.0	89	79
14	[1] 71	83	80	82	4.5	5.5	93	87
15	80	80	79	80	11.0	6.0	76	89
16	80	79	81	82	9.0	5.0	72	89
17	81	79	80	82	7.5	5.5	80	90
18	82	81	82	78	6.5	5.5	70	90
19	83	81	84	83	5.0	5.5	78	84
20	84	80	84	83	5.5	5.0	76	80
21	81	80	83	82	7.0	3.5	78	89
22	83	81	84	82	5.5	6.0	81	84
23	81	83	82	84	11.5	9.0	78	76
24	81	83	83	83	12.5	6.0	72	82
25	82	80	82	80	7.5	6.0	85	82
26	83	79	84	80	9.0	7.0	80	85
27	80	78	82	82	7.5	9.0	72	82
28	80	79	82	81	7.5	6.5	75	86
29	83	82	83	80	5.0	4.0	78	86
30	81	82	82	82	8.5	2.0	82	85
31	82	82	84	83	7.5	4.0	82	85

[1] Minimum.

RAINFALL.

In regard to the precipitation, the climate of the peninsula of Florida may be divided into a wet and a dry season, the wet season commencing about the middle of May and continuing three or four

months. Like other conditions of climate this feature is not governed by any hard and fast rule, but is subject to marked exceptions. During the dry season, October to May, there are frequent showers and often heavy rains. In February, 1899, there was a total rainfall of 11.53 inches at Kissimmee, while in the three months of July, August, and September the following year there was only 13.49 inches rainfall.

The following tables give the records of the rainfall at Kissimmee, in the northern part of the watershed, and at Jupiter, on the east coast opposite Lake Okeechobee, for a period of nine years, and represent fairly well the rainfall that may be anticipated in the Everglades:

Total rainfall, number of days of rainfall, and the maximum rainfall in 24 hours, for each month of the years 1898 to 1906, inclusive.

KISSIMMEE, OSCEOLA COUNTY, FLA.

Months.	1898			1899			1900			1901			1902		
	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.
January	0.23	1	0.23	5.72	9	1.11	4.22	8	1.16	0.92	3	0.55	0.19	1	0.19
February	1.12	3	.42	11.53	7	4.75	2.65	5	.91	2.46	5	.94	6.07	6	2.65
March	.....	.....	.....	1.68	4	.91	6.07	6	1.91	3.51	6	.80	1.88	4	1.17
April	.12	1	.12	3.06	4	1.64	3.02	6	1.05	3.23	3	2.91	1.73	4	1.00
May	.35	1	.35	1.60	1	1.60	5.84	7	3.00	2.96	3	2.30	.34	2	.23
June	5.75	6	1.50	3.06	7	.87	8.18	15	1.40	8.78	12	1.66	5.85	7	3.30
July	7.90	10	2.25	8.37	15	2.59	5.66	14	1.23	2.84	10	.58	5.36	12	2.10
August	11.41	15	2.20	11.06	15	2.95	3.23	4	1.48	9.91	19	1.35	7.27	9	2.39
September	4.52	10	1.47	7.03	10	2.68	4.50	7	1.96	12.95	11	4.60	6.35	15	1.35
October	5.17	13	1.43	15.98	7	9.50	4.83	8	2.67	1.18	3	.57	3.07	8	.76
November	.88	4	.25	.23	1	.23	1.62	3	1.00	.67	2	.52	1.15	3	.87
December	3.02	9	1.45	1.60	4	.94	5.09	6	3.25	1.35	3	.80	.96	2	.66
	40.47	....	.....	70.92	....	.....	54.91	....	.....	50.76	....	.....	40.22	....	.....

Months.	1903			1904			1905			1906		
	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.
January	4.76	8	1.66	4.16	8	1.40	0.70	2	0.62	6.43	6	3.34
February	5.04	6	2.71	5.16	5	2.12	.91	4	.67	1.49	4	.56
March	5.84	10	2.00	.80	3	.60	3.88	8	1.25	2.74	7	.93
April	.25	1	.25	2.25	4	.85	1.82	6	.60	1.48	4	.68
May	6.68	9	2.35	.51	4	.25	7.17	12	2.05	6.77	11	2.24
June	10.12	14	1.45	8.19	14	1.50	4.46	11	2.25	10.21	15	1.70
July	6.07	13	1.58	8.56	9	2.55	14.05	22	2.10	6.65	14	2.10
August	4.31	8	1.10	4.53	9	1.20	13.90	23	2.70	2.59	6	.82
September	12.06	14	2.95	4.66	10	1.30	4.94	9	1.50	3.26	8	.84
October	1.02	5	.31	6.72	12	1.55	3.19	5	1.40	2.00	6	.66
November	3.56	5	2.30	3.15	5	1.73	Trace.	....	Trace	.16	1	.16
December	1.51	3	1.09	.80	2	.70	9.43	15	3.20	.04	2	.02
	61.22	....	.....	49.49	....	.....	64.45	....	.....	43.82	....	.....

Total rainfall, number of days of rainfall, and the maximum rainfall in 24 hours, for each month of the years 1898 to 1906, inclusive—Continued.

JUPITER, DADE COUNTY, FLA.

Months.	1898			1899			1900			1901			1902		
	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.
January	0.36	6	0.13	4.30	17	0.94	3.49	15	1.01	8.29	12	4.94	0.98	5	0.75
February	.95	5	.55	4.64	12	1.78	2.28	12	.45	1.07	5	.40	4.64	7	1.70
March	3.26	7	2.28	3.58	5	2.05	8.20	8	3.69	2.30	8	.75	.97	7	.34
April	1.90	6	1.67	3.11	7	1.51	2.16	7	1.10	2.13	5	1.36	.97	5	.44
May	1.15	5	.60	1.65	7	.64	7.43	15	2.18	3.63	7	2.02	4.83	7	2.27
June	.12	3	.06	3.45	12	1.32	2.90	16	.73	17.41	13	7.45	3.92	10	1.69
July	6.80	11	1.70	3.35	14	.87	3.49	15	1.38	7.23	18	2.09	4.73	11	1.21
August	6.62	15	1.52	5.96	11	1.78	1.12	6	.48	12.13	21	1.77	1.91	13	.46
September	3.38	24	1.14	11.27	23	2.76	7.62	13	3.44	9.71	16	3.03	6.01	20	1.81
October	10.89	19	2.52	16.66	15	4.96	10.11	20	2.61	7.08	24	1.02	13.74	17	4.58
November	1.11	8	.71	.99	9	.53	.73	5	.50	.94	7	.82	2.38	13	.68
December	2.56	8	.87	2.97	13	1.37	3.10	11	.82	4.17	10	2.69	.71	3	.55
	39.10	....	.....	61.93	....	.....	52.63	....	.....	76.09	....	.....	45.79	....	.....

Months.	1903			1904			1905			1906		
	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number of days of rainfall.	Maximum rainfall in 24 hours.
January	6.98	15	3.33	2.56	13	0.93	1.40	8	0.76	2.62	13	1.19
February	4.50	9	2.41	2.10	6	.91	1.50	10	.95	6.44	9	3.62
March	9.27	17	2.49	3.06	9	2.30	5.39	11	1.88	2.50	12	.98
April	.44	5	.31	2.85	6	2.52	3.14	7	2.47	2.57	7	.96
May	2.71	9	1.26	2.42	14	.77	3.35	8	1.01	7.04	16	2.64
June	7.01	18	1.52	10.54	18	2.46	2.08	11	.93	11.90	12	5.75
July	3.23	15	.88	4.38	14	1.08	9.12	18	1.83	7.97	20	2.71
August	2.47	14	.69	5.79	15	2.00	10.72	21	1.78	8.55	22	2.02
September	15.82	21	6.59	8.92	16	2.44	10.77	16	2.32	8.37	10	5.62
October	1.81	10	1.05	21.39	14	10.48	4.26	16	1.46	8.31	17	5.08
November	2.50	14	1.12	3.68	13	1.20	2.88	9	2.01	4.53	4	3.16
December	.56	5	.21	.49	8	.19	15.18	26	5.75	.05	1	.05
	57.30	....	.....	68.18	....	.....	69.79	....	.....	70.85	....	.....

EARLY STATE LEGISLATION RELATING TO THE EVERGLADES.

Florida was admitted into the Union in 1845, previous to which time the agricultural possibilities of the Everglades had scarcely been noticed. The soil was supposed to be fertile, but nothing positive was known upon this point. It was suspected by some that the interior might be lower than sea level, in which case the drainage of so large an area would be difficult. The first act of the State legislature was the adoption of the following joint resolution. (See p. 34):

Whereas there is a vast and extensive region, commonly termed "The Everglades," in the southern section of this State, embracing no inconsiderable portion of its entire peninsula, which has been hitherto regarded as wholly valueless in consequence of being covered by water at stated periods of the year and the supposed impracticability of draining it; and

Whereas recent information, derived from the most respectable sources, has induced the belief, which is daily strengthening, that these opinions are without foundation and, on the contrary, that at a comparatively small expense the aforesaid region can be entirely reclaimed, thus opening to the habitation of man an immense and hitherto unexplored domain, perhaps not surpassed in fertility and every natural advantage by any other on the globe; and

Whereas it is no less the interest of the General Government than of Florida, with its vast donation of unlocated land, to adopt some early and efficient measures to test the accuracy of these representations: Be it therefore

Resolved by the Senate and House of Representatives of the State of Florida in General Assembly convened, That our Senators in Congress be instructed, and our Representatives requested, to bring this important subject to the attention of Congress at the earliest day, and earnestly press upon its consideration the propriety and policy of forthwith appointing competent engineers to examine and survey the aforesaid region.

This resolution was properly signed and transmitted to the President, James K. Polk. Evidently no action was taken by Congress, and two years later, 1847, the Legislature of Florida passed resolution No. 14, which reads as follows. (See p. 39):

Whereas large tracts of the public lands lying in the vicinity of Lake Okeechobee, and in that region south of said lake called "The Everglades," being covered with water, are incapable of being surveyed and subdivided and are therefore valueless to the United States; and

Whereas it is believed that a large portion of said lands may be drained by canals, reclaimed, and made valuable for the cultivation of tropical plants and fruits; and

Whereas it is believed that these lands, if reclaimed, would not only remunerate this State for the expense of such reclamation, but would yield a considerable surplus above such expense: Therefore,

Resolved by the Senate and House of Representatives of the State of Florida in General Assembly convened, That Congress be requested to grant to this State all of said lands lying south of Caloosahatchee River and of the northern shore of Lake Okeechobee, and between the Gulf of Mexico and the Atlantic Ocean, on condition that the State will drain them and apply the proceeds of the sale thereof, after defraying the expense of draining, to purposes of education.

Like requests were made of Congress by Louisiana, Arkansas, and other States for the swamp and overflowed lands within their respective domains. In response to these numerous appeals from the several States, Congress passed in 1850 an act commonly known as the "swamp-land grant," which was approved by the President and became effective September 28, the same year. This law (sec. 2479, Rev. Stat.) reads as follows. (See p. 67):

To enable the several States to construct necessary levees and drains to reclaim the swamp and overflowed lands therein, the whole of the swamp and overflowed lands made unfit thereby for cultivation and remaining unsold on and after the 28th day of September, A. D. 1850, are granted and belong to the several States, respectively, in which the said lands are situated.

Section 2480 of the same statutes provides as follows:

The proceeds of said lands, whether from sale or direct appropriation in kind, shall be applied exclusively, as far as necessary, to reclaiming said lands by means of levees and drains.

THE SWAMP LANDS OF FLORIDA AND THEIR MANAGEMENT.

Under this grant the State of Florida has received and accepted from the Federal Government up to June 30, 1907, 20,458,866 acres of swamp and overflowed land, which is nearly two and one-half times the combined area of the States of New Jersey, Connecticut, and Rhode Island.

By an act of the legislature passed January 6, 1855, the State of Florida created a Board of Trustees of the Internal Improvement Fund of the State, consisting of the governor, attorney general, comptroller, treasurer, and commissioner of agriculture, and vested in said Trustees title to all of said swamp and overflowed lands for the use and purpose mentioned in said act. (See p. 69.) There has been more or less discussion as to the obligation imposed upon the several States by the acceptance of swamp and overflowed land from the Federal Government. In the case of Kimball *v.* The Reclamation Fund Commissioners (45 Cal., 344), the supreme court of that State said:

> In accepting this grant the State was bound to carry out in good faith the objects for which it was made. It would practically defeat the whole cause of reclamation contemplated by Congress if the mere sale of land to private proprietors should have the effect to exempt it from the power of the legislature to reclaim it. Such a result would be a flagrant violation of its duty toward the Federal Government.

In Fourth Wallace, page 143, the Supreme Court of the United States held that the acceptance of this grant by the State constituted a contract, and that the contract required the State to appropriate the lands granted to it for the purpose of reclaiming them.

The personnel of the board of trustees of the Internal Improvement Fund has been frequently changed by the election of new State officers. (See p. 19.) These changes have been detrimental to the adoption and carrying out of any fixed policy concerning the drainage of the State swamp lands. The Trustees have usually held the opinion that these lands should be drained, but how or by whom has been an open question. Plans for draining the land have been proposed from time to time, and spasmodic efforts have been made to discharge the obligation imposed on the State by the acceptance of these lands from the Federal Government, but comparatively little has been accomplished along these lines.

A CONTRACT TO DRAIN THE EVERGLADES.

In February, 1881, the Trustees of the Internal Improvement Fund entered into a contract with Hamilton Disston and his associates, of Philadelphia, Pa., under the terms of which agreement the said Disston and his associates agreed to drain and reclaim all the overflowed lands in the State of Florida practicable to be drained, lying south of township 23 and east of Peace Creek. (See p. 20.)

Disston subsequently formed a corporation under the laws of the State of Florida, known as the Atlantic & Gulf Coast Canal & Okeechobee Land Co., for the purpose of carrying out his contract with the State, and the Trustees of the Internal Improvement Fund, on September 1, 1881, accepted this corporation, in lieu of Disston and his associates, for draining these lands.

The boundary of the area to be drained was changed from time to time, but was permanently fixed by a resolution of the Board of Trustees as approved. (Vol. 3, p. 223, of the published proceedings.) As its compensation for draining these lands the drainage company was to receive a part of the land as set forth in the contract. The company constructed some dredges and entered upon the work as provided for in its contract and dug a number of canals in the northern part of Osceola County, near Kissimmee, which lowered the level of some lakes in that vicinity and drained a large amount of

marsh land adjacent to the canals and lakes. The company also dug some canals south and west of Lake Okeechobee, but they did not lower the water sufficiently to afford drainage for any part of the lands in that section of the country. The location of the several canals constructed by this company is shown on the map. The value of the work accomplished and the amount of land drained became a matter of much public discussion and criticism. During the years 1883 and 1884 the Trustees of the Internal Improvement Fund evidently acknowledged that the terms of the contract were being carried out, and in payment for work claimed to have been done deeded to the drainage company 1,175,303 acres of land. Frequent complaints and public utterances concerning the matter created a certain amount of friction between the Atlantic & Gulf Coast Canal & Okeechobee Land Co., and the Trustees of the Internal Improvement Fund, and ultimately attracted the notice of the Legislature of the State of Florida, which enacted a statute in 1887 authorizing the Trustees to make an amicable adjustment of the differences existing between them and the drainage company and arrange a compromise that would protect the interests of the State and secure a prompt and vigorous prosecution of the work of drainage and reclamation agreed upon under the terms of the contract. A compromise was effected and a new contract entered into that took the place of and superseded all previous contracts that had been made. Under the terms of this new contract it was agreed that the drainage reserve of said company should be reduced and limited so as to secure to the company a total of 2,000,000 acres of land, including that which had already been conveyed to the company. These lands were to be selected in a body as near as might be of alternate sections within the reserve held for said company, and such selections were to be filed with the Trustees.

This compromise contract stipulated that upon the completion of certain work, estimated to cost $75,000, which was partly constructed, the Board of Trustees should release all claims for land previously conveyed to the drainage company. It was further agreed that in the reclamation of the land still left in the drainage area the Atlantic & Gulf Coast Canal & Okeechobee Land Co. should expend the further sum of $206,264 and should receive in payment 1 acre of land for each 25 cents expended in drainage, which would make the total amount of land to be received by this drainage company from the State of Florida 2,000,000 acres.

The work was continued under this contract, and on December 31, 1893, the Atlantic & Gulf Coast Canal & Okeechobee Land Co. filed a statement setting forth that they had economically and in good faith expended in the completion of the work within the drainage area the entire sum specified in said contract, and had moreover expended $27,154.58 in excess of the requirements of the contract in the belief that the Trustees would extend the contract on similar terms. The Trustees, however, refused to do this, and the work ceased at that time. Numerous controversies arose, growing out of this contract, which have not yet been fully settled. In 1895 and 1898 the drainage company received deeds from the Trustees for 542,918 acres of land, making a total of 1,652,247 acres, and is still seeking to recover 347,753 acres more in order to complete the total of 2,000,000 acres provided for in the compromise contract.

DRAINAGE WORK BY THE STATE.

From the time the work was suspended by the Disston Land Co. in 1893 until 1904 the matter was frequently discussed, but no drainage operations were undertaken by the board. In that year the question of draining the Everglades became one of the leading issues in the State election. The Hon. N. B. Broward was elected governor and became ex officio president of the Board of Trustees of the Internal Improvement Fund, which board was pledged to the people to drain this land. In 1906 the Trustees erected two large dipper dredges in New River, near Fort Lauderdale, and commenced the work of cutting two canals 70 feet wide and 10 feet deep in a westerly direction into the Everglades. (Pl. I., fig. 1.) This action on the part of the board aroused a sharp discussion upon the feasibility of the undertaking, its value to the State, and the probability of the successful completion of the work and ultimate conversion of the Everglades into productive lands. The operations of the Disston Land Co. had been confined to the lands lying above Lake Okeechobee, although tentative plans for draining the Everglades had from time to time been proposed. It was urged by objectors that too little reliable information regarding the problem was at hand to warrant so large an undertaking. While the State board possessed the data gathered by various expeditions, some being of an engineering character, but for the most part purely casual and descriptive, it was desired that an investigation be made to obtain accurate data and gather information concerning the physical characteristics of the Everglades and their economic value, should complete reclamation be found feasible, in order that a plan of drainage might be developed.

INVESTIGATIONS BY THE UNITED STATES DEPARTMENT OF AGRICULTURE.

In order to secure such an investigation, the State Board of Trustees of the Internal Improvement Fund requested the cooperation of the Secretary of Agriculture. The magnitude of the work and the public interest manifested in the agricultural possibilities of the Everglades led to a favorable consideration of the matter, and the Office of Experiment Stations, which has direction of drainage investigations of the department, was authorized in 1906 to proceed with such work as would be required to secure the desired information.

In outlining a plan of procedure it was decided that the office would utilize all the reliable data that had been collected by others, and also carry on a line of original examinations and surveys to get specific data necessary for the proper consideration of the drainage problem. Much useful information was found in the reports of the United States Army officers and engineers and in special reports submitted to Congress. The surveys made by the Disston Co. and maps and documents collected by the Board of Trustees of the Internal Improvement Fund were also valuable. These various documents were carefully studied and such facts as had a bearing on the work were compiled and classified for further consideration. From these sources a comprehensive view of the general features of the existing status of the project was obtained. Many of the examinations recorded in these reports, however, had been confined to the coast and rivers, so that information regarding the interior was meager and unsatisfactory.

PRELIMINARY INSPECTION.

With a view of selecting the best place to commence this survey and determine the methods to be followed in carrying it on, J. O. Wright, supervising drainage engineer, who was placed in general charge of the investigation, made an examination of the southern part of Florida in November, 1906. After skirting the Everglades on both the east and west sides and ascending the Caloosahatchee River as far as Lake Hicpochee and interviewing numerous trappers and hunters, the magnitude of the undertaking and the difficulties attending the work became more apparent. This inspection disclosed the fact that from Palm Beach to Miami, though there are frequent towns along the Florida East Coast Railroad, there are no settlements that extend more than 2 miles west of the railroad. The swamp and saw-grass marsh present an unbroken front for more than 60 miles. Not a road or permanent trail crosses this vast wilderness south of Lake Okeechobee. Not a sign of habitation, except possibly an occasional Indian hut, is found in all this 4,000,000 acres of almost impenetrable swamp. Beyond the fringe of timber, 2 to 8 miles wide along the coast, the ground is so soft and miry that a horse or ox can not walk on it. In a few places circuitous leads of shallow water were found, through which a small boat could be pushed with a pole, but they were not sufficiently connected to be of any use to an exploring party. The prospect of entering the Glades from the east side with a camp equipment and implements for doing engineering work was not inviting. The hunters and trappers who had some knowledge of the interior maintained that it was a physical impossibility to cross the Everglades except in small boats during periods of high water.

An examination of the west side of the peninsula revealed the fact that there was a large area of low, flat woods bordering the Everglades, with but a single settlement, consisting of a trading post and a mission church, located 25 miles south of Lake Okeechobee and 70 miles from Fort Myers. This settlement is commonly known as "Brown's store" or the "Glade Cross Mission."

The supplies for this settlement are brought overland from Fort Myers in wagons usually drawn by oxen. Owing to the impassable condition of the roads, or rather to the lack of roads, it takes a week to make a trip, and but half a ton of merchandise can be hauled at one load. From Brown's store north to the Caloosahatchee River the woods are comparatively open and can be crossed with horses by avoiding the numerous ponds and some of the deepest sloughs. A few miles south of Brown's store the forest is more dense and the ground so soft that a team of any kind can not be used. Some of the higher ridges in this section are inhabited by the Seminole Indians, whose number is estimated at from 500 to 700. They live by hunting and fishing, and Brown's store is their principal rendezvous. These Indians are not savage, but entertain a distrust and hatred toward any employee of the United States Government, and would render no assistance either as guides or helpers.

After considering the difficulties that had to be met in carrying on this survey, it was decided that it would be more practicable to commence operations at Fort Myers, establish a base of supplies at Brown's store, and cross the Glades from west to east. Under this

plan, if it became necessary from any cause for the field party to change its course in the interior of the Glades and come out at a point farther north or south than had been planned, means of communication and stores where supplies could be procured would be found near at hand; while if crossing from east to west, should it be impossible to land at Brown's store, there would be no means of communication near by and no supplies within a week's journey. Furthermore, the Caloosahatchee River is the only navigable outlet from Lake Okeechobee, and it seemed desirable to use it as a means of entering the lake.

ORGANIZATION AND WORK OF THE FIELD PARTIES.

In accordance with the above plan, field parties were assembled at Fort Myers in January, 1907, in charge of John T. Stewart, drainage engineer of this office; Lawrence Brett, of Kansas; E. W. Chadwick, of Pennsylvania; and Paul Funderhide, of North Dakota, being commissioned assistants. Local helpers were employed as needed, including I. S. Singletary, of Fort Myers, who served as guide during a part of the investigations. The following general instructions, setting forth the object of the investigation about to be undertaken, were issued to the party:

(1) To determine the topography of the country lying south of township 41, so as to locate proper channels to carry the overflow of Lake Okeechobee to the sea along the natural and most practicable routes.

(2) To determine approximately the extent, area, and character of the watershed of Lake Okeechobee, so as to calculate the discharge capacity of the channel or channels necessary to prevent the overflow of the lake.

(3) To determine the depth of muck and to locate the rim of the stone which encircles the lake or skirts or crosses the Everglades.

(4) To analyze the different kinds of soil found and determine their value for agriculture.

(5) Make plans and estimates of cost of a complete system of drainage.

A mean Gulf tide level was determined at Fort Myers, and a permanent bench mark was established. This was checked by a bench mark previously established by the United States Army engineers. Level party No. 1, consisting of four men in charge of Mr. Brett, with team and wagon, 9 by 9 foot tent, necessary camp equipment, and rations for 25 days, started from Fort Myers January 10 and ran a line of levels east along the Caloosahatchee Valley to Lake Hicpochee, as shown on the map. Frequent measurements were made of the river channel to determine its carrying capacity. There is a fairly good road from Fort Myers to Fort Thompson, and but little difficulty was experienced in this portion of the work; but from Fort Thompson to Lake Okeechobee there is no road, and some parts of the way were so swampy that it was difficult to transport the camp equipment. It was not possible to take the team beyond the point marked "Travers House" on the map. The men waded the swamp and continued the line in the direction of Lake Okeechobee until a point was reached where there was no slope in the surface of the water for several miles. This condition extended to the open water of Lake Okeechobee.

From the "Travers House" the line of levels was turned in a southerly direction, continuing along the edge of the flat woods skirting the Everglades to Brown's store. Side levels were run occasionally eastward into the body of the saw grass. This part of the route abounds in ponds and sloughs and no little difficulty was experienced both in running the line and in moving camp. Along the entire course from Fort Myers to Brown's store numerous bench marks were established whose description and elevations are given in the latter part of this report.

The notes of this survey show that the water level of Lake Okeechobee at that time was 20.6 feet above mean tide at Fort Myers. Turning south along the western boundary of the Everglades, at a distance of 10 miles the elevation is 20.1 feet; at 20 miles, 18.8 feet; at 23 miles, 18.2 feet; at 27 miles (at point opposite Brown's store and the beginning of a line run eastward across the Everglades), 14.2 feet, thus showing a fall of 4.6 feet toward the south in the last 7 miles of the course and also showing that the surface at this point was 6.4 feet below the surface of the water in the lake.

Level party No. 2, in charge of Paul Funderhide, with rodman and teamster, supplied with 15 days' rations, ran a level line from Fort Myers southeasterly along the trail to Brown's store. The two parties reached Brown's store about the same time, February 9, and closed the circuit of levels. The close agreement of the two lines established the accuracy of the work. This line passes over the divide between the waters of the ocean and the Gulf which, near Immokalee, reaches an elevation of about 38 feet. Two of the men were sick and had to return to Fort Myers with the team that brought out supplies, and another was so affected by rheumatism that he could hardly walk.

LAND CONDITIONS WEST OF THE EVERGLADES.

While the two level parties were running the lines described above, John T. Stewart, in addition to sending supplies from Fort Myers to Brown's store, made an examination of the country between these two points and also of that on the west side of the Everglades from the Caloosahatchee River to a point 14 miles south of Brown's store. He was accompanied by I. S. Singletary, a guide, timber estimator, and surveyor, the trips being made in a light 2-horse wagon.

The following definitions of the terms commonly used in describing the vegetation peculiar to Florida in and about the Everglades are taken from I. S. Singletary's notes. They are essential to a clear understanding of the condition of the country as given in this report.

Pine timber land.—"Flat wood" or "slash pine," the trees being tall and straight, 80 feet high and sometimes 4 feet in diameter. The pine forests are interspersed with flag ponds and long open sloughs. The soil is sandy and in some cases rocky and is usually dry when other land is covered by water.

Cypress timber land.—This is true swamp and is covered with water the greater part of the time. The soil is largely muck, but outcroppings of sand and rock occur. The trees are draped with gray moss.

Prairie.—The Florida prairie is open flat land covered with wire grass, saw grass, saw palmetto, and sometimes dotted with thickets and pine islands.

Saw palmetto beds.—The saw palmetto is an unusual and characteristic growth of the drier lands. It is common in the pine lands and on the prairies where a slight elevation occurs. It consists of clumps of fanlike leaves which may attain a height of 6 feet but usually not more than 3 feet. The fans shoot out from large root stocks 5 or more inches in diameter, which creep along on the surface, sometimes reaching a length of 9 feet.

Pine islands.—These are isolated clumps of pine timber ranging in size from a few trees to many hundred acres, and are scattered throughout the prairie and cypress country. They indicate a dry and sandy soil.

Cypress heads.—Like pine islands, cypress also appears in isolated clumps, but these heads always indicate low, wet ground, which is usually covered with water during the entire year.

Hammocks.—A hammock is distinguished by its growth of hardwood trees and a noticeable absence of pine. It is usually a little higher than the surrounding land and possesses a dark sandy soil.

Ponds.—These are depressions which are filled with water during the rainy season and support a luxurious growth of vegetation. They are usually designated by the vegetation which is most prominent.

(1) Saw-grass ponds. The grass is found growing from 2 to 12 feet high in either muck or marl land. It has a saw-tooth edge and is often so rank and thick as to be impenetrable.

(2) Pop-ash ponds. These are low, containing as much as 2 feet of water in the summer. The pop ash is a low scrubby tree seldom growing higher than 25 feet. It grows in clusters, 12 or more stems often coming from a single root.

(3) Flag ponds. In these grow the "fire flag," a kind of lily, which reaches a height of 10 feet, and has a leaf similar to the banana plant; also the "lily flag," which is found in both sand and muck soils, and resembles the stiff-stemmed lily of the north.

(4) Maiden-cane ponds. The bottom of these ponds is usually white sand. The cane is a tall, slim, graceful grass, which grows from 2 to 6 feet high. Good drinking water may always be found in these ponds at a depth of a few feet.

A brief description of the country traversed by the trail followed by level party No. 2 from Fort Myers to Brown's store is important as showing the relation of its topography and vegetation to that of the Everglades.

From Fort Myers for a distance of 32 miles the land is sandy and the woods are sufficiently open to permit a view for a half mile in any direction. At Immokalee is a hammock covered with hardwood trees, the surface being 38 feet above sea level and the highest point on the route. It is estimated that about one-fourth of the land is open prairie and the whole is diversified by sloughs and an occasional lake. Cypress heads are found in the deeper channels. The course of drainage in the sloughs is southward, the fall of the surface from Immokalee southeasterly to the Everglades at Brown's store being 23 feet.

Passing from Brown's store south for about 14 miles through alternate prairies and cypress swamp the "Big Cypress" was reached. This was so soft and boggy that a horse could not be driven over it. At this point the water from the Everglades breaks over toward the west into the "Big Cypress." North of this point the alternate

sloughs and ridges parallel the border of the Everglades in such a manner as to prevent the drainage of the country from entering the Everglades except during times of excessively high water.

THE SURVEY ACROSS THE EVERGLADES.

An important part of this investigation was to extend a level line across the Everglades in order to ascertain the elevation of representative points in the interior, to learn the character of the vegetation and soil, and particularly the depth of the muck to the underlying rock. As previously stated, the elevation of a point at Brown's store had been checked by two lines of levels. Of the two parties which had run the levels only a sufficient number remained to equip one. Mr. Stewart placed Lawrence Brett in charge, with E. W. Chadwick and Paul Funderhide as assistant engineers, and Bob McCloud and Rob Allen, of Fort Myers, and S. A. Anderson, of Miami, as boatmen and general helpers. The following account of the equipment used and progress made in running a line of levels directly west across the Everglades from Brown's store is taken from Mr. Brett's notes:

As boats are necessary for travel and transportation of equipment in the Everglades, three Indian canoes were secured at Brown's store. These were "dugouts" made from cypress logs, being from 14 to 20 feet long and 16 to 30 inches wide, and were poled along by a man standing in the stern. It can readily be seen that it required considerable practice to navigate these successfully through the narrow and tortuous leads through the saw grass. They were of light draft, however, and well suited to the work. A most meager camp outfit was carried. One 9 by 12 feet tent fly sufficed for the party, and in addition each man had his own roll of bedding, consisting of a small comfort, a double blanket, and that necessary adjunct, a mosquito bar. These latter were of box shape, with heavy muslin tops and sides of cheese cloth, sufficiently long to tuck under the blankets and prevent the intrusion of insects, frogs, and occasional snakes. As no wood is obtainable in the western part of the Glades, a 2-burner oil stove was used, making it necessary to carry a considerable amount of oil. The rations consisted of such staples as rice, bacon, ham, corn meal, sugar, coffee, and a few canned goods.

The surveying outfit comprised a Y level equipped with standia wires, several prismatic compasses, and a pair of field glasses. The regular level tripod was soon found too short for use in the soft, mucky soil; so seasoned cypress poles, 9 feet long, were substituted for the regular legs.

An experimental trip was first made by running a line of levels for 8 miles into the Glades. Finally, on Monday, February 18, all but one of the party left Brown's store with the hope of carrying the line at least to the center of the Glades. The bench mark, where the line had formerly ended, was reached by a day's trip, and the next morning the line of levels was once more taken up. The mean depth of the muck was nearly 6 feet and the saw-grass strands made very rough traveling, thus making it very difficult for the supply boats to keep up with the level party.

The daily routine was as follows: On breaking camp in the morning the level party would start from their turning point, which was a 6-foot steel pipe, with an extra joint for emergencies. This could be pushed through the soft muck to the solid sand or rock beneath and gave for each location the depths of both surface water and muck and the elevation above sea level of the sand or rock bottom. Fire was employed to clear the path for the instrument men, for the growth on the saw-grass strands with its accumulation of dead grass was so dense in some places as to form an impassable barrier. The saw grass, being of cellular structure, explodes when burning, so that when large bodies of it are burned the sound of the many reports may be heard for miles and the densely black smoke given off may be seen a great distance. The Indians at the mission kept track of the daily progress of the party by this smoke or "sign," as it is locally called.

After the first 10 miles the wide saw-grass strands caused much labor, as the boats had to be dragged one at a time from one lead to another. This work often took the united effort of the entire crew, thus, of course, much delaying the instrument work. As these leads run generally north and south it would have been much easier to run the line in that direction. Usually at 4 o'clock in the afternoon the whole party prepared camp for the night. A pile of saw grass about 9 feet wide by 12 feet long was made, using scythes to cut the grass. When the pile was sufficiently high the

tent fly was spread over it and the mosquito bars were hung from horizontal poles which were lashed to the boat poles stuck upright in the muck. These camps were known as "gator nests," from their resemblance to the original. It took four members of the party to make camp while the others were preparing supper. The oil stove proved difficult to handle in the steady trade winds which sweep across the Everglades, consequently the cooking was none too elaborate. The only bread it was possible to make was a thick flour pancake. Coffee, bacon, and rice were easily prepared, and the monotony of the last two articles was varied by substituting at times ham and grits. If sundown came before supper was finished it was necessary to complete the repast in bed, as the mosquitoes made any other location untenable.

When the line had been continued for 18 miles from Brown's store the oil gave out, so the entire party returned to the mission for oil and supplies, taking three days for the trip. As the water in the Glades was lowering rapidly, on March 4 a new start was made with three canoes heavily loaded with supplies, and on the evening of March 6 the bench mark was reached, and early the next day the line to the east was continued. On the evening of March 11 the middle of the Everglades was reached, and the water in the leads and shallow ponds gave out. A large area of nearly dry land was encountered, so after a day had been spent in exploring north, south, and east from the line, with no trace of water except to the west, the boats had to be abandoned. Another day was spent in preparing for the new mode of travel. All the remaining flour was fried into hard cakes, the rice, bacon, coffee, and sugar were placed in cloth bags, about two-thirds of the personal belongings and bedding was discarded, and the tent fly was cut up to make pack straps. Each man carried his own bedding and a portion of the rations and surveying equipment. The levelmen and rodmen carried their shares as rolls, while the others made shoulder packs. The average weight of each pack was 75 pounds.

For two days splendid progress was made, as the saw-grass strands were much more solid than previously. Drinking water was obtained by digging holes with the hands, sometimes a foot deep, and the way was cleared by keeping fires burning almost continually. The next day, March 16, the nature of the Glades again greatly changed, the leads becoming deeper and in many places very soft and boggy in the bottom. The saw-grass strands were also grown up with myrtle bushes, which, from a distance, gave the impression of a low line of timber. About noon a small hammock or willow head was reached. The tallest trees, about 15 feet high, were climbed, and all the party were convinced that they saw the timber on the east coast. "Hellelujah Hammock" was the name given to the place as indicative of the feelings of the party, and a flag was hoisted bearing the inscription "U. S. Department of Agriculture," as well as the names of the members of the party. Notes were also left on the trees for the benefit of later comers. In the afternoon very slow progress was made and a terrific thunder and wind storm caught the party with no camp made, so the supper consisted of some of the fried cakes. At 7.30 o'clock that same night the spirits of the party were once more raised upon discovering the flash of a searchlight against the black clouds, and on examining the map it was concluded that the flash came from some ocean vessel in the vicinity of Miami. The next day was St. Patrick's Day, as well as Sunday, and the leads were so deep and the men so hampered with their loads that but a half mile's progress was made in the afternoon. That night an inventory disclosed the fact that, even by cutting each man's rations in two, there was only food enough left for two days. It was therefore imperative to abandon the line for the time being and get to the east coast as quickly as possible. Most of the equipment was left on a pile of saw grass, covered by an oilcloth, and early the next morning the party pushed on, each carrying only his mosquito bar, blankets, and rations. The long-continued work in the water had scalded all the men's feet, and the many wounds and scratches from the saw grass had become poisoned from the various water plants and exposure, so the whole party were seriously crippled. Two days were spent in reaching the edge of the Glades, and on March 20 the breakfastless party left the Glades and continued east through the cypress and pine woods until they reached a road which brought them to Pompano at 1.30 o'clock in the afternoon. The greater part of the next week was spent in eating, sleeping, and curing the injured feet and wounds. Five and six meals per day was a not uncommon program, as the exertions and privations of the party had been extreme.

A new outfit having been procured, a new start was made on March 26 from Fort Lauderdale, following the north fork of the New River into the Glades. The party, consisting of Brett, Funderhide, McCloud, and John Ashley, was equipped with two canoes and supplied for 10 days. Five days were spent in reaching the point where the line had been abandoned, as, on account of the canoes, much zigzagging north and south was necessary in order to make the few miles toward the west. On Easter Sunday the line was continued, and at noon of April 4 the edge of the Glades was reached and the line tied to a bench mark set by Chadwick and Rob Allen, who had remained in order to bring the tide elevation of the Atlantic to this point.

As may be surmised from the above, many difficulties and dangers were encountered, but, although there were narrow escapes from the numerous snakes, and some alligators were encountered, and uncontrolled fires often became very threatening, still none of the party was seriously injured or ill. During the 52 days occupied in running this, the first line of accurate levels through the heart of the Everglades from the Gulf to the Atlantic, the greatest loyalty, perseverance, and endurance was shown by every member of the party, and much valuable data of an engineering nature was secured. As the men were worn out from their arduous task, it was decided to discontinue the work till another season.

Reviewing the course of the survey party for a record of further details, some interesting and valuable facts should be noted. The season was more than usually dry, as indicated by the constant lowering of the water as the line was pushed across the expanse of the Glades. A profile of the level line across the State beginning at tide level at Fort Myers and extending to Brown's store and thence east across the Everglades to tidewater on the Atlantic coast is shown on Plate II, figure 1. A representative section of the Glades is shown on Plate III, in which the relation of the surface and underlying sand or rock appears.

The following condensed statement represents the prominent characteristics of the country as given in the notes of Mr. Stewart and Mr. Brett:

Elevations southeasterly from Fort Myers to Brown's store.

	Feet.
Sea level at Fort Myers	0.0
General surface, 3 miles southeasterly	19.9
General surface, 12 miles southeasterly	27.7
General surface, 20 miles southeasterly	30.7
General surface, 25 miles southeasterly	25.0
General surface, at Immokalee	37.7
Water surface of Lake Trafford	20.0
High-water mark, Lake Trafford	22.0
General surface, 6 miles east of Immokalee	28.0
Water surface of Okaloacoochee slough	25.3
Surface of land near Okaloacoochee slough	27.0
Surface near Rock Lake	24.0
Water surface of lake	21.0
Surface, 8 miles southeasterly from Rock Lake	21.0
Surface, 4 miles west of Brown's store	17.7
Surface, 1 mile west of Brown's store	17.0
Extreme high-water mark of Everglades at Brown's store	16.3
General surface of muck at Brown's store	14.6

Elevations across the Everglades east from Brown's store.

	Feet.
Surface of muck, 5 miles east of Brown's store	14.0
Surface of muck, 20 miles east of Brown's store	13.0
Surface of rock, 20 miles east of Brown's store	8.0
Surface of muck, 30 miles east of Brown's store	12.6
Surface of rock, 30 miles east of Brown's store	8.0
Surface of muck, 40 miles east of Brown's store	11.6
Surface of rock, 40 miles east of Brown's store	10.0
Ridge at Osceola's Camp	18.7
Surface, 4 miles west of Pompano	12.3
Surface, at Pompano	11.0
Low tide at Fort Lauderdale (one observation)	.6

The depth of the muck along this line varies from 1 to 6 feet, averaging possibly about 4½ feet. The top soil is a turf composed largely of grass roots, except in the leads and shallow basins, where the saw grass does not grow. Here the vegetation is more completely decayed and is so loose when saturated with water that the pedestrian sinks to the bottom sand or rock. The "leads" filled with water and lilies alternating with saw grass give a deceptive undulating appearance as one looks across the expanse, though, as will be noted, the slope easterly in a distance of 40 miles is only 32 inches. Scattered at random throughout the saw-grass marsh, but more particularly near the eastern edge, there are small islands or portions of the surface which are elevated slightly above the marsh level. At these places the sand or rock is usually found near the surface. They are covered with a growth of scrub bushes with occasionally a clump of pines or cypress trees. The combined area of such islands, however, is insignificant, being probably less than one-half of 1 per cent of the entire saw-grass marsh.

The people of southern Florida speak of the "upper and lower" Glades, the former term being applied in general to the marsh between Okeechobee and the north line of township 51 and the latter to the territory south of that line. This division is shown on the map, though there is in reality no defined line between the two. There is but little soil on the rock in the lower Glades, and the saw grass is less dense than in the upper Glades. The upper Glades, covering approximately 2,000,000 acres, have the deeper muck and much the greater agricultural possibilities. The State dredges which were found working near Fort Lauderdale uncovered numerous salt-water shells in the sand at a depth of 13 feet below the surface. There are water trails through the Everglades well known to the Seminole Indians, who frequently traverse them in their dugout canoes during periods of high water. They rarely penetrate the saw grass of the interior, but confine themselves principally to the islands and the timbered edges of the Glades and the water leads through which they make their way to the east coast when in need of supplies.

The results of the few months' work may be briefly outlined as follows: A line of levels had been run across the State, and the depth of the muck along the line where it crossed the Everglades had been determined by soundings taken along its entire length. A fall of 2.7 feet had been found from west to east across the Everglades. The surface along a line 30 miles south of Lake Okeechobee is 9 feet lower than the ordinary stage of the water in the lake and 11.6 feet above sea level. The rock rim on the east side of the Glades is from 5 to 7 feet higher than the surface of the Everglades. The high-water level of the lake is 22 feet above tide. The Everglades lie high enough above the sea to admit of drainage by gravity. The surface of the upper Glades slopes southeasterly. The overflow from Lake Okeechobee floods the Everglades except in the dry season of the year.

A portion of the water in the southwestern part of the upper Glades flows southwesterly through the Big Cypress Swamp and thence to the Gulf.

INVESTIGATIONS DURING THE WINTER OF 1907–8.

Examinations so far had shown that Lake Okeechobee would be a controlling factor in any plan that might be developed for draining the Everglades. The water of the lake should be so controlled that it would not overflow along the south border and flood the marsh land, as now happens each year.

The fact was recognized that if the surface of the lake should be permanently lowered 4 or 5 feet a considerable zone of land adjoining the lake shore would be favorably affected. The shortest line from the lake to the ocean, that easterly to the Atlantic, had not been examined. The investigations which it now appeared wise to make were:

(1) To ascertain by a line of levels and by soundings the feasibility of a drainage channel from the lake easterly to the Atlantic coast.

(2) To estimate the probable effect of lowering the lake upon the lands which immediately border it and also to determine the character of this land.

(3) To canvass the feasibility of improving the Caloosahatchee River and making it a more complete outlet for the lake westerly into the Gulf.

With the purpose of pursuing investigations along these lines Mr. Lawrence Brett and party began the investigation of a line from Palm Beach northerly and westerly to the lake.

A sea-level bench mark was established and levels were run along possible outlet lines, entering the lake at the point on the southeastern coast of the lake. This line is 30¼ miles long and is the shortest route from the lake to tidewater. No rock was encountered on this line, and the highest point, 27 feet above tide, is shown on Plate II, Figure 2.

EXAMINATION OF LAKE OKEECHOBEE.

In order to facilitate the examination of the lake, the Board of Internal Improvement Fund furnished a gasoline launch with attendant, which started with the party from Fort Myers the latter part of March, 1908.

The only means of getting into Lake Okeechobee is by way of the Caloosahatchee River and the connecting canals. At the time the party went into the lake the upper river was very low and much difficulty was experienced in getting a boat of 13-feet beam and drawing 26 inches of water up this stream. There was a good stage of water from Fort Myers to Labelle, and this portion of the journey was made in 1 day, while it required 15 days of hard work to complete the remainder of the journey to the lake.

At Fort Thompson the river cuts its way through a rock ledge which comes to the surface and extends a long distance both north and south. At low-water stage the rapids here are very swift and there is a fall of about 3 feet in one-fourth of a mile. It was necessary to build a dam in order to get the boat over these rapids. About one-half a mile above the rapids is Lake Flirt, a large shallow body of water whose average depth is not over 3 feet during the rainy season. The bed of the lake has been filled by sedimentation and the growth of aquatic plants. It became necessary to turn the boat around and cut a channel through the vegetation and sediment with

the propeller in order to effect a passage. This required much time and patience, but was the only means by which the boat could be taken through the lake. A canal known as the Wood Yard Canal is cut through the upper end of the lake for a distance of about 3 miles. This canal was originally 50 feet wide and 6 feet deep. It is filled with sediment until it now has a cross section at low water of about 3 by 10 feet. Above this canal is upper Lake Flirt, very shallow and having no definite channel for navigation. Above Lake Flirt there are 2 miles of canal 60 feet wide by 5 feet deep, but grown full of reeds and aquatic plants. Bonnet Lake lies between this canal and the upper Caloosahatchee River. It, too, like Lake Flirt, is shallow and filled with sand and vegetation, which greatly impedes navigation. From the upper Caloosahatchee the Reedy Canal, 60 feet wide by 7 feet deep, leads to Lake Hicpochee.

This canal is in fair condition, but its bed is covered with weeds and moss, which wrapped around the shaft of the propeller and made it frequently necessary for one of the party to climb overboard and dive under the boat and clean the wheel. From Lake Hicpochee to Lake Okeechobee there are two canals. The northern one, known as the "Three-mile Canal," is the one usually traveled; the southern one, the "Nine-mile Canal," is badly grown up with hyacinth and water lettuce, and at most seasons of the year is almost impassable, even for a small canoe. With the exception of a few temporary fish camps around the borders of the lake, its shore is absolutely uninhabited, and it is said to be the loneliest body of water in the United States. The only industry around the lake is the fish trade. Catfish are caught in nets in great abundance, carried to Fort Myers, and shipped from that point to St. Louis and other inland towns. The fish boats furnish the only means of communication between Lake Okeechobee and Fort Myers. Above Fort Thompson there is no settler except Mr. Woodhull, a fisherman, who has a camp on the bank of the Three-mile Canal near the lake.

Lake Okeechobee is circular in shape, about 30 miles in diameter, and is the largest fresh-water lake wholly within the United States, except Lake Michigan. At mean level it contains an area of 468,860 acres. At high stage its surface is about 22 feet above tide level, and at low stage about 19. The lake is quite shallow, the deepest places not exceeding 22 feet at low water, and the average depth being about 12 feet. In the southern portion it contains several islands, some of which are 2 or 3 miles in extent, very low and swampy, and covered with a dense growth of custard apple, scrub oak, myrtle, and in some places a few cypress, all interwoven with a network of vines.

The shores of Lake Okeechobee are not well defined, except on the east coast, where there is a stretch of 25 miles of sandy beach, with well-defined banks. The rest of the coast line is flat and marshy and is covered with a thick growth of vegetation. As the lake rises its waters inundate this flat country and the shore line moves out, in places several miles, so that the area of the lake is much greater at high than at low water. Even the bed of the lake on the south and west side is covered with a growth of aquatic plants that impedes the progress of a boat and in some places makes navigation impossible. The bed of the lake, except in the southern part, is a fine, hard sand, and presents a comparatively smooth and even surface. The soundings disclose no deep holes or channels,

and no rock is found except in the vicinity of Chancy Bay. The lake has no tide, but its surface is easily affected by the wind, and it is not uncommon to find the water at least 1 foot higher on one side than the other, due wholly to the influence of wind pressure. The water in the lake, when not agitated, is clear and wholesome, and is regarded by hunters and fishermen, who frequent the lake, as extremely healthful. Until within recent years this lake had no well-defined outlet to the sea, but during the rainy season its water rose to an elevation of about 21 feet, when it commenced to overflow its banks from the mouth of Fish Eating Creek on the west, around the south side, to a point on the east several miles north of Pelican Lake, a distance of probably 70 miles. With such width of overflow, it matters not how hard it might rain, it would be impossible for the lake to reach a higher level than 22.5 feet.

At the southern end of the lake there are half a dozen streams varying from one-quarter of a mile to a mile in length which flow out into the saw grass of the Everglades and gradually subdivide until they disappear. During the dry season, when the lake is low, the water from these streams flows into the lake. From the south shore of the lake is a canal known as "South Canal," which extends 13 miles into the heart of the Glades. At periods of high water the lake overflows through all these channels on the south side and spreads its waters over the vast area of saw-grass marsh.

About 1884 a canal 70 feet wide and 6 feet deep was completed from the Caloosahatchee River at Fort Thompson up through Lake Flirt, Bonnet Lake, and Lake Hicpochee, making a direct and well-defined channel into the lake. During the period of high water this channel furnishes a good stage for navigation, but during the dry season, when the surface of the lake is lowered to an elevation of 20 feet or less, there is not enough water in these canals to make a boating stage for anything but small gasoline launches.

Since these canals have been cut and the current of the water turned into the Caloosahatchee River, it has overflowed its banks below Fort Thompson, doing great injury to the orange and grapefruit groves that line the banks of this stream on both sides for many miles. In order to lessen or prevent this overflow, a fund was raised by the interested parties and a dam constructed across the canal at the west end of Lake Hicpochee. This interfered with the navigation of the stream and it was destroyed by parties who opposed the work.

THE COUNTRY SURROUNDING LAKE OKEECHOBEE.

The flat woods are found east of the Kissimmee River and Lake Okeechobee, extending from the north line of the watershed to the Hillsboro River in township 47, and on the west side cover a greater part of Polk, De Soto, and Lee Counties. This scope of flat pine land is by no means all covered with timber. It is crossed at random by numerous sloughs and marshes a mile or more in width and is dotted here and there with ponds in which are no trees, and in many places there are broad stretches of sedge and wire-grass prairie. The combined area of these open stretches is probably 40 per cent of the entire area herein designated as "flat woods." The pine trees are not thick on the ground except in a few places. They average about 15 inches in diameter, are from 60 to 100 feet tall, and contain a great deal of

pitch, which is objectionable in lumber. They make excellent piles and yield large quantities of turpentine. The soil of the pine land is sandy and as a rule is dry when the rest of the country is under water, so that the occurrence of pine is looked upon as an indication of high land, but even such land in a rainy season is covered with water many inches deep. A large percentage of the pine woods is covered with saw-palmetto beds which choke out every other form of vegetation. The palmetto bed is no indication of good soil; and the plant, so far as known, has no use.

That portion of the pine woods not covered with palmetto beds produces a growth of wire grass and sedge which makes fair grazing for cattle. If the palmetto could be killed out the value of the flat woods for grazing would be greatly increased, but as it withstands both dry and wet weather much better than the grasses it is apparently on the increase. In some places crossing the flat woods there are sloughs or depressions, more or less connected, a little lower than the adjacent country, in which is found an alluvial soil underlaid with clay. This land is frequently covered with small cypress or a dense undergrowth of vines and small trees. The copious rainfall of the wet season drenches the entire land, and every depression, little or big, becomes a natural reservoir, storing up the water in quantities, which frequently last throughout the year. Here and there in these pools is found a luxuriant growth of grasses, whose growth and decay through centuries has formed in the bottom of the ponds a deposit of rich muck. The different species of grasses do not flourish together, so each has occupied certain ponds exclusively. These ponds are designated locally by the kind of vegetation growing in them, as saw-grass pond, lily pond, flag pond, and maiden-cane pond. They are numerous, but not large, and the soil in them appears to be fertile.

The sedge and wire-grass prairies are most extensive north and west of Lake Okeechobee, often extending for 20 or 30 miles, unbroken except by a few scattering pines, but in which occur frequent beds of saw palmetto. These prairies have a smooth surface, are apparently perfectly level, and during the rainy season are covered many inches deep with water. The soil is usually a white sand with occasional spots of loam. There are prairies of the same kind scattered throughout the woods on the east side of Lake Okeechobee. Some attempts have been made to cultivate some of them, but owing to the lack of drainage the crops have been destroyed during the wet season and most of the projects undertaken have been abandoned. An inspection was made of a piece of this kind of land in cultivation about 8 miles west of Lantana on the east coast. It was surrounded by an embankment to keep out the water and by using plenty of commercial fertilizer produced good crops of tomatoes, but there was no provision made for pumping the water out from within the embankment, so when the rainy season came on the field was a pond instead of a vegetable garden.

The most prominent of the streams which enter the lake on the north is the Kissimmee River, which has a valley 4 to 12 miles wide covered with saw grass, which grows luxuriantly on a deep muck soil. The channel is bordered by a growth of willows, pop ash, scrub oak, custard apple, and myrtle. It winds back and forth across the valley in a tortuous course, the distance in direct line between Lake Kissim-

mee and Lake Okeechobee being 60 miles, while the boat must pass a distance of 150 miles in going from one lake to the other. The level of the river even at low water is nearly the same as the surface of the muck lands bordering it, while during the rainy season the entire valley becomes a lake. This river, with Fish Eating Creek from the northwest and numerous smaller streams from the northeast, bring to the lake vast volumes of water during the rainy season, which is from June to October. This lake, having no adequate outlet, discharges its surplus water over the south border into the Everglades through the small fanlike channels before described. Thence the water passes slowly through the "leads" and vegetation of the marsh until it reaches the sea.

METHODS OF DRAINING THE EVERGLADES.

From an analysis of the existing conditions it is clear that in order to reclaim the Everglades as a whole it will be necessary to control the level of the water in Lake Okeechobee. A narrow strip along the east edge of the Everglades could probably be reclaimed in parcels by building a substantial embankment on the western border of a tract and cutting drainage ditches into the small streams that flow into the Atlantic Ocean, but this plan would not accomplish the reclamation of that part of the Everglades adjacent to Lake Okeechobee, which is considered the most fertile and valuable land. This part in particular must be protected from the overflow of Okeechobee if it is to be utilized for agriculture.

It has been claimed by some explorers that the lake is fed by subterranean streams or large springs, and for that reason its overflow can not be controlled or regulated. A thorough examination at low water failed to disclose any such sources of supply. If there be any, they are so small that they have no appreciable effect on the level of the lake. The height to which the lake rises depends entirely upon the amount and intensity of the rainfall over its watershed and its stage of water at the beginning of the rainy season.

The drainage of the Everglades involves the consideration of two problems:

First. The best means of controlling the water in Lake Okeechobee, so that it will not overflow its banks during the rainy season and yet will retain sufficient water to irrigate the lands when needed, and also to maintain a sufficient stage of water in the outlet canals for navigation.

Second. To provide adequate and proper drainage for the lands when protected from the overflow of the lake.

Both are equally important and merit careful and critical consideration.

Two plans have been proposed for preventing the overflow of Lake Okeechobee. One is to build a levee from the highland on the west around the south shore to the high bank on the east, and thus impound or hold back the rainfall during the wet season, and the other is to construct one or more canals from Lake Okeechobee to the Atlantic Ocean and to the Gulf of Mexico, and discharge sufficient water in this manner to prevent the lake from overflowing its banks.

The first plan is open to many serious objections. Owing to the depth of muck, which ranges from 8 to 14 feet along the south mar-

gin of the lake, and the absence of suitable material along the line of the proposed levee with which to build it, its construction would be very expensive. The muck might be removed by dredges and solid material hauled in from the pine woods, and a levee constructed, but this would necessitate the building of a trestle to support a track on which to bring in the material, which, together with the expensive methods of handling, would make the cost prohibitive.

The lake in its present condition does not rise to a higher stage than 22½ feet above sea level, because the lake then overflows its banks along the entire south shore. If its waters were confined by the levee it would reach a greater height, probably 25 or 26 feet. A levee to hold back this head of water and be strong enough to withstand the action of the wind and waves should be at least 3 feet above any possible level the lake might attain. Assuming 25 feet above sea level to be the maximum height of the lake, the top of the levee should be at least 28 feet to have a reasonable margin for safety. The elevation of the muck is approximately 22 feet above sea level and its average depth along the line of the proposed levee 12 feet. Under these conditions a levee to hold back the water of the lake should be at least 18 feet high, with a 3-to-1 slope on the shore side and a 2-to-1 on the land side. Such a levee would contain 190,080 cubic yards per mile, and, at the current prices for such work, including the excavation of the muck channel, building trestle for track, and loading and transporting suitable material, would cost at least 35 cents per cubic yard. This estimate makes the cost of the levee $66,528 per mile and the cost of 80 miles $5,302,240. In addition to the enormous cost this plan has other objections. It would back the water up on the opposite side of the lake and impair the drainage of a large area of land, some of which can be reclaimed and made fit for agriculture. Nor does it provide for water transportation across the State, which is a matter of no little importance.

The character of the soil in the Everglades is such that a constant supply of moisture is required to support and mature plants. During the winter and spring months the precipitation in southern Florida is not sufficient to supply the need of growing crops if the ground water is too far removed. In order to develop the fertility of the Everglades and make them sufficiently productive, water should be stored in Lake Okeechobee to supply the deficiency to the land during the dry period and provision should be made to remove the excess water so as to prevent overflow. This can best be accomplished by a system of outlet canals, provided at the upper end with gates, to regulate the flow of water into them.

The watershed drained by Lake Okeechobee, including the area of the lake, is approximately 4,000,000 acres. There is no authentic record of the rainfall in this area except at Kissimmee, in the northern portion, but it will be safe to assume that the rainfall at this station represents fairly accurately that of the entire watershed. The average annual rainfall at Kissimmee for the past nine years was 53 inches (see table, p. 146), with a minimum of 40.22 inches in 1902 and a maximum of 70.92 inches in 1899. This amount of rainfall is not uniformly distributed throughout the year, but is excessive during the summer and fall, often exceeding 12 inches in a single month. In the months of July and August, 1905, the total rainfall recorded at Kissimmee was 27.95 inches. During the same period there were

but 20 inches at Jupiter, 24 inches at Fort Myers, and 25 inches at Miami. This would seem to indicate that the rain at Kissimmee was due to some local influence, and that probably the rainfall over the entire drainage area for that time did not exceed 26 inches. As a fall of 26 inches in any other two consecutive months is the nearest approach to this amount, it is safe to conclude that 26 inches in two successive months is an extraordinary rainfall, not likely to occur except at rare intervals. Since a rainfall of 18 to 22 inches in two consecutive months has occurred three times during the last decade, we may reasonably expect the same amount in the future. In order to have a fair margin of safety, it will be assumed in these considerations that the maximum rainfall upon the entire watershed in two consecutive months is 24 inches.

EVAPORATION.

Rainfall disappears in two forms: (1) Run-off or free water which flows away in streams, and (2) evaporation, which includes water taken up by growing plants as well as that which passes into the atmosphere as vapor.

No observations have been made in southern Florida to determine the loss by evaporation in that latitude. Careful experiments, however, have been carried on in some of the Northern States, in the arid West, and in Europe to determine what percentage of the rainfall is run-off and what percentage is evaporation. While the results obtained vary with the local conditions, some general laws have been established by these experiments from which we may deduce fairly accurate conclusions. The most complete as well as the best-known series of observations on the evaporation from the surface of the soil are those made by Gilbert and Lawes at Rothamstead, England, 1870 to 1890. The English experiments show that in June, July, August, and September 76 per cent of the total rainfall during these months was removed by evaporation. Prof. E. F. Ladd, of the Agricultural College at Fargo, N. Dak., conducted a series of experiments in 1902 to 1905 to determine the loss by evaporation from a water surface. The average daily evaporation as shown by his report is as follows: May, 0.17; June, 0.21; July, 0.26; August, 0.24; and September, 0.11 inch.

The Croton River watershed in New York for a period of 32 years shows a mean annual evaporation of 25.74 inches, or 53 per cent of the rainfall, the greater portion of this evaporation occurring during the months of June, July, August, and September. At least 70 per cent of the total rainfall during these months is evaporated.

The volume of water which is taken up by vegetation during the growing season is large. Prof. F. H. King showed in experiments at Madison, Wis., which were made to determine the amount of water required to produce a pound of vegetable dry matter, that some crops use water equivalent to 25 inches of rainfall in the growing season.

Experiments made at Emdrup, Denmark, and quoted by J. T. Fanning,[1] show the following relative evaporation from water and long grass as determined by observations during a period of 10 years:

[1] Hydraulic and Water Supply Engineering, by J. T. Fanning.

From water surface, mean for June and July, 10.5 inches; from long grass, mean for June and July, 17 inches.

Mr. Fanning quotes experiments made in Lancashire, England, and at Whitehaven, England, to determine the evaporation from bare earth. At the former place the amount in June and July was 7.8 inches, and at the latter 8.3 inches.

A study of the details of numerous experiments of this character leads to the conclusion that where the surface is wet or covered with water, or with dense vegetation, and where the temperature is high—80° to 95° F.—and the percentage of humidity is less than 85, the conditions are favorable for a high rate of evaporation. It also shows that the evaporation from land covered with dense, short vegetation is much greater than from a water surface or from bare earth.

Reference has been made to the foregoing data for the purpose of showing the importance of evaporation as a factor in the drainage problem rather than of furnishing a specific guide in estimating the evaporation from the watershed of Lake Okeechobee.

Turning to the area under consideration, during the months of July and August, 1905, when 28 inches of rain fell at Kissimmee (see table, p. 146), the following conditions prevailed over the peninsula of Florida: The ground was either saturated or covered with water. The mean temperature was 79° F., the average wind velocity 8.5 miles per hour, and the humidity of the atmosphere 82 per cent. Under this condition of the atmosphere, and a dense vegetation covering a large part of the area, the evaporation was at least 0.3 inch per day during the entire period. This would be 9 inches per month, or 75 per cent of the rainfall for the months of July and August, which passed off as evaporation from the watershed of Lake Okeechobee.

RUN-OFF.

The difference between rainfall and evaporation is the run-off or drainage that must be provided for. It is estimated that the maximum rainfall that is likely to occur in July and August is 24 inches, or a mean daily precipitation of 0.387 inch. The difference between this amount and 0.3 inch, the estimated amount of evaporation, is 0.087 inch, which is the estimated mean daily run-off from the entire watershed.

The effect of the run-off from the land into the lake will be as follows: The land surface which discharges its run-off into the lake is seven and one-half times the area of the lake. The run-off being estimated at 0.087 inch per day, the lake would be raised 7.5 times that amount, or 0.65 inch per day, or 40.45 inches during July and August. The daily evaporation from the lake being estimated at 0.25 inch and the rainfall 0.387 inch, there remains 0.137 inch of water in the lake, or 8.49 inches, which, added to the run-off from the land, makes 48.94 inches, the amount which the level of the lake would be raised during July and August should the banks be high enough to retain it.

From the above facts it appears that the most feasible way to control the level of Lake Okeechobee is to dig canals from the lake to tidewater of sufficient capacity to reduce its level to an elevation of 16 feet just before the rainy season sets in, and allow a storage capacity for 36 inches of the run-off. There will then remain to be removed through the canals 12.94 inches during the 62 days, or 0.2088 inch in 24 hours. To accomplish this will require canals having an aggregate discharge of 3,938 cubic feet per second.

SIZE AND ARRANGEMENT OF CANALS.

In determining the number and proper location of these canals it will be wise to consider the cost of their construction, the character of the land through which they pass, and their possible use for transportation. A canal 40 to 80 feet wide and 5 to 10 feet deep can be cut by a modern dredge and the material placed on the bank without rehandling. Such a canal is more economically constructed than one of larger dimensions. If one large channel having the necessary capacity were constructed, not as much of the Everglade land would be benefited as though the same capacity were secured by cutting two or more canals extending in different directions from the lake. The advantages are, therefore, decidedly in favor of cutting a number of small canals having the necessary capacity instead of one large canal.

Since transportation across the State is a matter of great importance, it is desirable that the drains be so planned as to form an all-water route from the Atlantic Ocean to the Gulf of Mexico. The plan here recommended provides for a series of canals of sufficient capacity to regulate the stage of water in Lake Okeechobee and also provides adequate drainage for the lands through which they pass.

The first of these canals, marked "A–A" on the map (Plate IV), passes down the Caloosahatchee Valley, following the course of the present drainage. This has the advantage of being the shortest route and having the greatest fall per mile, but there will be a larger percentage of rock to excavate than on some of the other lines. This will materially increase the cost, but for the purpose of navigation it is desirable that this route to tidewater be used. In addition to taking off part of the excess from Lake Okeechobee, this canal will furnish adequate drainage for the entire Caloosahatchee Valley, and reclaim and make fit for agricultural purposes a large body of extremely fertile land.

There is grave apprehension that any enlargement of the upper portion of the Caloosahatchee will cause it to overflow its banks along its lower course and damage the citrus groves. Such will not be the case when Lake Okeechobee is lowered and the discharge brought under control. There will not be as much water brought down this channel as is now carried by it in time of high water. The flow is to be regulated by locks at the upper end, and only as much water permitted to enter the canal as the stream can carry without damage to property along its course. One object of the entire system of improvement is to make the flow more uniform and maintain a good boating stage during the period of low water.

The canal second in importance, marked "B–B" on the map, is the Hillsboro route, which leaves Okeechobee at Pelican Bay and extends in a southeasterly direction to the head of Hillsboro River. This route is not as short as one directly east from Lake Okeechobee to the Loxahatchee River, but the cutting is not so deep, and it affords drainage for a much larger area of agricultural lands.

These two canals, "A–A" and "B–B," are intended chiefly as a relief to Lake Okeechobee and for transportation across the State. They are made deeper than the other canals shown on the plan, and with proper locks a depth of 5 feet may be maintained throughout the year. This will furnish a good boating stage and be of great value to the agricultural and commercial interests of the State.

The other canals shown on the map, and which are approximately 8 miles apart, are primarily drainage canals, although they would be navigable for light-draft boats and barges, and would be useful in bringing in fertilizer and other supplies desired and transporting to market the crops produced. In addition to these, lateral feeders and small field ditches will be necessary to make the land fit for cultivation. The number and size of these ditches will depend largely upon the use to which the land is to be put. It will not require as much drainage for growing rice and grass as for cultivated crops. These field ditches will be small and not deep. Their cost will probably range from $2 to $4 per acre, according to the crop to be grown and the method of cultivation adopted.

In determining the size of the several canals it must be borne in mind that in addition to discharging 3,938 cubic feet per second from Lake Okeechobee, they must take the run-off from the territory through which they pass. Computing this run-off at the same depth that was determined for the watershed of Lake Okeechobee, there must be removed 90 cubic feet per second from each township below Lake Okeechobee discharging into these canals. This requires that the several canals be increased from the lake toward their outlets to carry this additional quantity without overflowing their banks during the period of heavy rains.

The dimensions of the several canals located on the map, together with the approximate amount of excavation required in their construction, are given in the following table:

Estimated excavation in proposed canals.

CALOOSAHATCHEE—A-A.

Section of ditch.	Length.	Fall per mile.	Depth of flow.	Velocity.	Average width.	Discharge.	Depth of cut.	Total excavation.	Amount removed.	Net excavation.
	Miles.	*Feet.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Cu. ft. per sec.*	*Feet.*	*Cubic yards.*	*Cubic yds.*	*Cubic yards.*
0 to 10....	10	0.86	8	3.00	60	1,440	10	1,173,400	586,700	586,700
10 to 22....	12	.86	8	3.10	70	1,736	10	1,649,150	494,500	1,154,650
HILLSBORO—B-B.										
0 to 10....	10	0.30	8	1.80	50	720	10	981,560	.....	981,560
10 to 20....	10	.30	8	1.90	60	912	10	1,177,870	.....	1,177,800
20 to 30....	10	.30	8	2.00	70	1,120	11	1,511,560	.....	1,511,560
30 to 44....	14	.50	8	2.40	70	1,340	12	2,226,600	.....	2,226,600
NORTH CANAL—C-C.										
0 to 10....	10	0.26	5	1.25	50	312	7	689,000	.....	689,000
10 to 20....	10	.26	5	1.30	80	520	7	1,099,200	.....	1,099,200
20 to 30....	10	.53	5	1.90	80	720	7	1,266,200	.....	1,266,200
30 to 45....	15	.53	6	2.00	80	960	8	1,884,150	.....	1,884,150
NORTH NEW RIVER—D-D.										
0 to 10....	10	0.26	5	1.25	50	312	7	689,000	.....	689,000
10 to 20....	10	.26	5	1.25	80	520	7	1,099,200	.....	.....
20 to 30....	10	.53	5	1.90	80	720	7	1,266,200	.....	1,266,200
30 to 39....	9	.53	6	2.00	80	960	7	1,130,500	.....	1,130,500
39 to 45....	6	.53	8	2.50	100	2,000	12	1,400,200	800,000	600,200

Estimated excavation in proposed canals—Continued.

MIDDLE NEW RIVER—E-E.

Section of ditch.	Length.	Fall per mile.	Depth of flow.	Velocity.	Average width.	Discharge.	Depth of cut.	Total excavation.	Amount removed.	Net excavation.
	Miles.	*Feet.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Cu. ft. per sec.*	*Feet.*	*Cubic yards.*	*Cubic yds.*	*Cubic yards.*
0 to 15....	15	0.26	5	1.25	50	312	7	1,033,500	.....	1,033,500
15 to 25....	10	.26	5	1.25	80	520	7	1,099,200	.....	1,099,200
25 to 35....	10	.53	5	1.90	80	720	7	1,099,200	.....	1,099,200
35 to 42....	7	.53	6	2.00	80	960	7	753,600	.....	753,600

SOUTH NEW RIVER—F-F.

0 to 13....	13	0.26	5	1.25	50	312	7	895,700	447,850	447,850
13 to 23....	10	.26	5	1.20	40	240	7	549,600	.....	549,600
23 to 33....	10	.26	5	1.30	70	455	7	962,000	.....	962,000
33 to 43....	10	.26	5.5	1.40	90	693	8	1,413,000	.....	1,413,000
43 to 53....	10	.53	5.5	1.90	90	940	9	1,590,000	.....	1,590,000
53 to 58....	5	.53	6	2.10	100	1,134	11	2,159,200	1,000,000	1,159,200

MIAMI CANAL—G-G.

0 to 10....	10	0.26	5	1.25	40	240	7	549,600	.....	549,600
10 to 20....	10	.26	5	1.25	70	455	7	962,000	.....	962,000
20 to 30....	10	.26	5.5	1.40	90	693	7	1,236,500	.....	1,236,500
30 to 40....	10	.26	6	1.50	90	810	8	1,413,000	.....	1,413,000
40 to 54....	14	.36	6	1.70	90	918	9	2,226,000	.....	2,226,000

WEST CANAL—I-I.

0 to 10....	10	0.26	5	1.30	90	585	7	1,236,500	.....	1,236,500
10 to 20....	10	.26	5	1.30	120	785	7	1,648,700	.....	1,648,700
20 to 30....	10	.26	5	1.30	150	1,010	6	1,766,500	.....	1,766,500
30 to 40....	10	.26	5	1.30	175	1,137	4	878,000	.....	878,000
Total.	350	.....	.....	.....	.....	.....	.....	.....	.....	38,287,270

NOTE.—Channels are computed rectangular. Combined discharge at lake, 3,993 cubic feet per second; combined discharge at outlets, 9,145 cubic feet per second.

ESTIMATE OF COST.

It is not possible to determine the exact amount of excavation without a survey of each separate line of canal, but the above estimate is sufficiently accurate to serve as a basis for computing the probable cost of the work. One important element entering into the cost is the amount of rock to be removed. This can only be known after the lines of canal have been definitely located and soundings made along each line to determine the depth of muck.

From examinations so far made it is estimated that about 20 per cent of the excavation required will be a mixture of sand and porous rock, similar to that found at New River, and the remainder will be pure muck or muck underlaid with fine sand. On this basis of classification there will be 7,657,454 cubic yards of rock excavation and 30,629,816 of muck and sand.

From the work done at Fort Lauderdale it has been demonstrated that with a good dipper dredge the rock can be handled at a cost not exceeding 8 cents per cubic yard. With a suitable equipment there

is no doubt that the muck can be removed at a cost of less than 4 cents per cubic yard. At these prices the total cost of the excavation would be:

7,657,454 cubic yards, at 8 cents	$612,596.32
30,629,816 cubic yards, at 4 cents	1,225,192.64
Total	1,837,788.96

This is approximately $1 per acre on the lands designated on the map as the upper Glades.

In order to control the water in these canals and regulate the flow they should be provided with gates or locks at both the upper and lower ends, and in some cases at intermediate points. Because of the slight heads, these would be comparatively inexpensive structures.

SOIL OF THE EVERGLADES.

The soil and natural vegetation of the Everglades has been incidentally described on previous pages. The possible value of the soil for agricultural production is a matter of the greatest importance to the State and is the sole reason for investigating the feasibility of draining the Everglades. The natural fertility of the soil, its lasting qualities, the staple crops it will produce, and the treatment which the land will require to yield a profit to the owner are subjects of sufficient moment to warrant a full discussion of the soils of the Everglades and a description of such examples of productiveness as will throw light upon this not yet fully settled question. The soil throughout the area is of vegetable origin and may be classed as either peat or muck. A definition of these two types as given by the Bureau of Soils [1] United States Department of Agriculture, is as follows:

Peat.—This is a vegetable matter consisting of roots and fibers, moss, etc., in various stages of decomposition, occurring as turf or bog, usually in low situations, always more or less saturated with water, and representing an advanced stage of swamp with drainage partially established.

Muck.—This type consists of black, more or less thoroughly decomposed vegetable mold from 1 to 3 feet or more in depth and occupying low, damp places, with little or no natural drainage. Muck may be considered an advanced stage of peat brought about by the more complete decomposition from water or from aeolian sources, resulting in a finer texture and closer structure. When drained, muck is very productive and is adapted to corn, potatoes, cabbage, onions, celery, peppermint, and similar crops.

The soils that may be classed as peat and those which may be called muck are frequently not clearly distinguished. They grade off from one to the other quite gradually and are disposed in an irregular way throughout the entire area. In general, the soil around the lakes, adjacent to the rivers, and along the course of the deepest and most constant flow of water is more thoroughly decomposed and contains a larger percentage of mineral matter than those portions which are less frequently submerged. The tributaries of Lake Okeechobee are not silt-bearing streams, and hence but little silt has been deposited in the Everglades. Under present conditions much of the fibrous matter, consisting largely of carbon, appears to be capable of resisting decomposition, even when exposed to the air. It dries out readily and when ignited burns slowly.

[1] Soil Survey Field Book, 1906, p. 206.

The principal growth in these peat and muck lands is saw grass (*Cladium effusum*), which grows from 5 to 12 feet high during summer and in winter and spring gets dry enough to burn. Large areas are often burned over by hunters and trappers. Other plants that are frequently found throughout the Glades are yellow pond lily, maiden cane, Wampee or pickerel weed, arrow weed, some sedges, and a few other aquatic plants.

In formation, structure, and composition of soil much of this land resembles quite closely some of the large swamps in southern Louisiana that have been drained and brought under cultivation and which to-day are yielding good crops of sugar cane, onions, and potatoes. The Louisiana marshes, however, have a larger percentage of silt mixed with the vegetable matter than the Everglade marsh, but are quite like the lands around Lake Okeechobee along the Caloosahatchee River and many of the smaller marshes throughout the wooded section. Numerous swamps in other parts of the country which bear a close resemblance to the Everglade land in color, texture, and formation have been drained and, after proper treatment, yield good crops, particularly of corn and vegetables. From these comparisons it appears that the stage of decomposition reached and the amount of mineral matter contained in the muck has a marked influence on its productiveness.

Examples of the productiveness of the saw-grass lands of Florida are not wanting, though there are none in the interior of the Everglades. In January and February, 1908, the land in the vicinity of Fort Lauderdale, where the State dredges had been operating, was inspected. The ditches had partially reclaimed some of the land and several fields were in cultivation. At that time the water in the canal was 2 feet below the level of the marsh.

The saw grass had been burned, leaving a heavy stubble. Large areas had been planted in tomatoes and small patches in potatoes, eggplant, snap beans, peppers, and turnips. The land was firm enough on the surface for a man to walk over it without sinking; but it was too soft to carry the weight of a horse and could not be plowed. A line was stretched to indicate the rows, and small hills were made with a hoe at intervals of 30 inches. A handful of fertilizer was mixed with the earth and the sprout or seed planted. The hills are cultivated with a hoe, and during the season practically all the "middles" between the rows are chopped out. It is claimed that the second year the land is in much better condition for cultivation. Two or three applications of fertilizer are usually made during the year at the time the plant is cultivated. This, the growers claim, is necessary to get marketable fruit. Without fertilizer the tomato vine grows tall and rank, but bears few tomatoes.

Near the banks of the canals and on some land along New River that had been in cultivation two or more years the ground was much more firm and would carry the weight of a team of horses. When the drainage is completed, so as to prevent the annual overflow of this land, and the soil water is kept 3 or 4 feet below the surface, there is little doubt that these lands can be plowed and cultivated by the usual methods. At the present time cultivation is expensive, as the work has to be done by hand and the fertilizer distributed through the fields by means of wheelbarrows moved on boards laid down to form a temporary run-

way. The products also have to be carried out in baskets or taken out in wheelbarrows over these runways.

On the edge of the Everglades, northwest of Miami, another truck farm was inspected. Here the muck was not so deep and contained a larger percentage of silt than did the saw-grass marsh above described. The land had been broken and cultivated with teams in the ordinary way. On February 26 the tomatoes were large enough to commence shipping. The crop was fair and would probably yield 100 crates per acre.

On the west shore of Lake Okeechobee, at the entrance of Three-mile Canal, another cultivated tract was inspected. The vegetation has been removed from a typical piece of saw-grass muck, the surface of which was flooded during the period of high water; but at the time of the visit, March 25, 1908, it was 28 inches above water level. The muck on this tract was firm on top and soft below for a depth of 12 feet. The proprietor was growing Irish potatoes, onions, beets, cabbage, snap beans, corn, tomatoes, lettuce, and peas. Everything was in a most flourishing state—potatoes as large as hen's eggs, beets 6 inches in diameter, onions almost as large, cabbages with solid heads 20 inches in diameter, snap beans in bloom, and corn a foot high. No fertilizer or manure of any kind had been used. The muck at this place was well decomposed and contained more mineral matter than the fibrous soil in some other localities.

On the south shore of Pelican Lake two trappers were found who had a small garden. They were growing onions, cabbage, peas, turnips, and tomatoes. The muck was 14 feet deep and the water, at the time of the visit, 24 inches below the surface. No fertilizer had been used and the plants were thrifty and promised an abundant yield.

On the north shore of Lake Okeechobee, near the mouth of Taylors Creek, a small portion of land had been cleared by the fishermen who were located there and planted in oranges and grape fruit. The trees were large enough to begin to bear and gave promise of producing an abundance of good merchantable fruit.

The most extensive test of the possibilities of these muck lands when drained was made a number of years ago near Kissimmee, Fla. Here the Disston Land Co. drained about 1,400 acres of saw-grass muck around Lake Tohopekaliga and cultivated extensive fields of sugar cane. The land was well drained by large open canals, and some of it was underdrained by means of mole ditches. Prof. W. L. Van Dusen, who was connected with the Disston enterprise at St. Cloud for a number of years, states that he personally tested the yield of a field of cane on this farm by measuring the land and weighing the crop that went to the mill, and by actual weight he found it to be 63 tons per acre. (See Pl. V.) Samples of this cane were taken at the time and tested by the Bureau of Chemistry of this department and showed 12 to 13 per cent sucrose. This, the chemist states, would yield 200 pounds of sugar per ton of cane.

Mr. J. O. Wright visited this sugar plantation in January, 1892, and saw large quantities of sugar cane that had been grown on these drained muck lands and which was being ground and manufactured into yellow clarified sugar at the sugarhouse erected by the Disston Co. at St. Cloud. Since that time the cultivation of cane has been abandoned, the sugarhouse has been dismantled, and the machinery

and appliances shipped to Mexico. The question is often asked, What brought about this change; why was the land which produced such great crops of cane abandoned and the expensive sugar mill removed? An investigation seems to indicate that the failure was due to mismanagement and lack of experience on the part of those conducting the business rather than to a failure of the lands to produce profitable crops of sugar cane. Laborers employed on the place for a number of years say that where the land was properly cultivated it yielded a heavy tonnage of cane, but a great loss was sustained in harvesting this cane and manufacturing it into sugar. The vegetation now growing on this land indicates that with proper methods of cultivation it would yield profitable crops.

At Southport, 16 miles south of Kissimmee, on a tract of drained saw-grass marsh, an orange grove with trees nine years old was inspected. (See Pl. I, fig. 2, facing p. 150.) These trees are strong and vigorous, and bore a large crop of oranges in 1907. Mr. Lee, the owner, says he never used a pound of fertilizer on these trees until 1908, when he gave the land a dressing, as he thought it might improve the quality of the fruit. This orchard, when visited in March, 1908, was very dry, and its condition would have been improved by irrigation.

CHEMICAL COMPOSITION.

Chemical analyses of muck soils are useful and instructive when studied in connection with climatic conditions and vegetation. One of the earlier investigations of Florida muck lands was made at the experiment station established by this department at Runnymede, Osceola County, about 200 miles north of the south shore of Lake Okeechobee. The following analyses, with explanations and comments, are taken from the report of the work at that station for 1891.[1]

Analyses of muck at Runnymede.

Samples dried at 110°.	Carbon.	Hydrogen.	Volatile.	Absorption.	Nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Soil No. 1:					
First foot	57.67	4.48	90.00	145.14	2.24
Second foot	47.07	5.15	72.00	108.50	1.40
Third foot	8.52	.53	15.00	46.68	.31
Soil No. 2:					
First foot	56.21	6.08	91.70	151.15	2.33
Second foot	58.57	6.04	96.50	188.32	2.83
Third foot	48.27	6.34	96.76	156.98	2.33
Fourth foot	21.72	2.03	40.88	81.05	.95
Soil No. 3	18.72	2.72	45.60	114.03	1.26
Soil No. 4	19.48	2.69	45.70	167.95	1.18

Sample No. 1 was taken from the front part of the station near the cypress grove, and No. 2 from the back part of the station near the pine land. They represent two distinct characters of muck. The first has a brown color, is very porous, and drains easily. No. 2 has a deep black color, is more compact, and is less easily drained. No. 3 was taken from a field on the St. Cloud plantation which has been cultivated in vegetables for five years. No. 4 was taken from a field on the St. Cloud plantation which has been in cultivation in sugar cane for five years.

Under the column "Absorption" is given the percentage of water which perfectly dry soils will absorb. It is seen that the pure muck, where unmixed with sand, will absorb more than its own weight of water; in one case almost double its weight. The

[1] Report of the Secretary of Agriculture for 1891.

importance of this property in times of drought and in relation to subirrigation must not be overlooked. In dry muck which has not been cultivated the value of the nitrogen reaches in one case $10.19 per ton, estimating nitrogen at 18 cents a pound. Cultivation for a few years reduces the percentage of nitrogen in the surface soils, as indicated by the numbers obtained with samples 3 and 4.

Analyses of several muck soils were made at the State experiment station of Florida in 1896. A few are here quoted, together with the comments which accompany them.

Florida muck soils.[1]

	Sample No. 16.	Sample No. 53.	Sample No. 98.[2]		Sample No. 16.	Sample No. 53.	Sample No. 98.[2]
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
Nitrogen	1.23	1.45	1.39	Phosphoric acid	0.15	0.11	Trace.
Insoluble residue	59.80	43.06	50.38	Chlorin	Trace.	Trace.	0.01
Potash	.02	Trace.	.51	Sulphuric acid	.14	.12	.05
Soda	.50	.13	.02	Carbonic acid	3.49	.00	.....
Lime	4.00	.15	Trace.	Water and organic matter	29.66	53.07	35.69
Magnesia	.00	.09	Trace.				
Ferric oxid	.39	3.25	3.66				
Alumina	2.20		9.03				
					100.35	99.98	99.35

[1] Florida Sta. Bul. 43.
[2] Analyzed by Bureau of Chemistry, U. S. Department of Agriculture.

Sample No. 16 was sent from Lemon City, Dade County, and is a mixture of soil and subsoil to a depth of 3 feet. The growth upon it is principally saw grass interspersed with maiden cane, lilies, etc. It appears to be seriously deficient only in potash. It is unusually rich in both nitrogen and lime, and is well supplied with phosphoric acid.

Sample No. 53 is reclaimed bay muck in the vicinity of Kissimmee, taken at a depth of 14 inches. The growth upon it was bay, cypress, willow, etc., and was more decomposed than the subsoil. It is very deficient in potash.

Sample No. 98 was taken at the depth of tillage from a field at St. Cloud which had been cultivated in cane for five years.

Several samples of muck were collected by Mr. Brett and his party while running the level line across the Everglades in February and March, 1907, from which two representative ones were selected for chemical analysis. They were examined for lime, potash, phosphoric acid, and nitrogen only.

Muck soils from the interior of the Everglades.

	Soil No. 8.[2]	Soil No. 11.[3]
	Per cent.	*Per cent.*
Lime	2.25	2.21
Potash	.15	.08
Phosphoric acid	.19	.19
Nitrogen	3.16	2.58

[1] Analyses by the Bureau of Soils, U. S. Department of Agriculture.
[2] Taken 8 miles west of Pompano.
[3] Taken 18 miles west of Pompano.

The samples were brown in color and composed largely of undecayed roots and other vegetable matter.

A comparison of these analyses shows that the saw-grass muck of the Everglades is strikingly similar to that of the Kissimmee Valley in the essential elements of plant food. The soils may, however, be quite dissimilar in compactness and density, the same volume of soil from different localities containing quite variable quantities of

plant elements. It is noted also that the nitrogen shows a material diminution after five years of cropping. Soundings made at various points indicate quite definitely that the muck in the vicinity of Lake Okeechobee, especially on the south side, is deeper and more compact than on the greater part of the land farther south. It is safe to assume that the deeper muck will be the more lasting under cultivation.

With the help of the analyses of several samples of muck soils in the State, some taken from fields newly reclaimed, some from fields which have been cultivated for five years, and others from the heart of the Everglades, a fairly intelligent opinion of the fertility of the Everglade lands can be formed. In this connection, however, it may be well to heed the caution of A. W. Blair, chemist for the Florida Agricultural Experiment Station, expressed in a bulletin upon soil studies.[1] With reference to the value of such analyses he says:

> It is generally admitted that the productiveness of a soil can not be determined by a mere chemical analysis alone. The analysis will show what elements are present and in what quantities, but it does not show what is absolutely available for the immediate use of the plant. Of two soils showing great similarity in chemical composition the one may be highly productive and the other unproductive. The reasons for this may possibly be found in different moisture conditions, or a difference in the physical texture, or in the difference in the amount of available plant food, or in a combination of all these differences. The chemical analysis, however, is of value in showing what the possibilities are under proper treatment.

Dr. Albert R. Leeds, of Stevens Institute of Technology, Hoboken, N. J., made a special examination of the Everglades to determine the fitness of the climate and soil for the growth of sugar cane. In his report, made in 1897, he says:

> Summing up all of the evidence that I have been able to obtain, both in the laboratory and by actual observation on the spot, I am convinced that the cultivation of sugar cane on the reclaimed muck lands around Okeechobee would be successful and the investment of the necessary large capital to cultivate and mill the sugar cane at this locality would be rewarded with an unusually large profit.

Osgood Welsh, another expert on the production of sugar, in comparing the muck lands of Florida with the sugar lands of Cuba, says:

> The Hicpochee-Okeechobee district is an ideal field for the agriculturist, and is, in my judgment, a place in which sugar cane can be produced at the least cost, because it possesses advantages of climate, soil, drainage, irrigation, fertilizer, cheap transportation, and the best facilities for the use of mechanical power in all the details of agricultural art.

While the above are mere opinions upon the matter, they are entitled to consideration, since they are based upon both chemical and physical examinations.

WILL DRAINING THE EVERGLADES AFFECT THE CLIMATE?

According to the best authorities on climatology, large bodies of water tend to temper the climate of land along their shores, due to the fact that water both absorbs and gives off heat at a much slower rate than land, thus maintaining a more constant temperature, and that air, having passed over water, would be cooler on a warm day and warmer on a cool day than the land over which it passes. There is some question as to how far this influence is perceptible, especially from air passing over comparatively small bodies of water such as lakes.

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[1] Florida Sta. Bul. 87, p. 19.

Prof. Winchell, from South Carolina, who made examinations on Lake Michigan, says:

> If the Lakes have any influence on the temperatures, it must be only a slight differential effect. Isotherms for July show that stations on opposite sides of Lake Michigan have precisely the same temperature. Experiments on Lake Ontario show the same results. Isotherms for January show that the west coast of the lake is 5° to 10° cooler than the east; that is to say, air between 20° and 30° grows slightly warmer by blowing over the frozen lake.

The area of Lake Okeechobee is small when compared with Lake Michigan or Lake Ontario, and its influence on the climate of the adjacent lands must be correspondingly less. If it has any effect on the air passing over its surface tending toward the prevention of frost it is very slight and extends but a few miles. In the plan of drainage here proposed it is not intended to drain Lake Okeechobee, but to lower its level about 4 feet, so that any climatic influence it may possess will not be destroyed.

Prof. R. De C. Ward, assistant professor of climatology in Harvard University, in concluding some remarks on this subject, says:

> Finally, it is clear that man, whether by reforestation or deforestation, flooding a desert or draining a swamp, can produce no important or extended modifications of natural climate, which is governed by factors beyond human control.

After reviewing the available evidence upon the subject it appears, because of the comparative narrowness of the peninsula and the great expanse of water upon either side, that the small amount of water on the surface of the Everglades does not have any appreciable effect upon the climate. It should be observed that this portion of Florida lies in the same latitude as the extreme southern part of Texas, where frosts rarely occur, though protected by water on one side only.

CONSERVATION OF WATER.

Muck lands in general are peculiarly susceptible to drought. The Everglades, lacking the silt and clay constituents in the soil and resting on sand or rock, will at times become too dry for crops unless provision is made to control the height of the water in the proposed drainage ditches. There will be danger from fire unless the soil be kept in a moist condition by means of controlling gates or stops in the ditches.

On the lands near Fort Lauderdale, adjacent to the canals recently constructed, the water plane was lowered 2½ feet and held at that level during the season. The truck growers cut the grass on this land with a scythe, let it dry a few days in the sun, and then set fire to it. It burned up clean without igniting the muck. The same was true on some lands that were cleared at the head of the Three Mile Canal. In the vicinity of Kissimmee, where the water has been kept 5 or 6 feet below the surface for several years, the muck becomes quite combustible during a dry season, and in some instances has caught fire and burned over several acres a foot or more in depth. This does not occur where the water in the ditch is held near enough to the surface to keep the soil moist nor where the muck is thoroughly decomposed.

The unequal distribution of rain is one of the characteristics of the Florida climate. The trucking season begins in September and lasts until May. It is during this season that rains are less frequent, and

frequently the grower is subject to grave danger from drought. The citrus groves and vegetables often suffer at this time from lack of moisture. It is during this same period that sugar cane is planted, and if the ground is too dry the cane may be affected by dry rot.

The ideal condition for agriculture is one in which the amount of moisture is under control. When there is too much moisture there should be some means of promptly removing the excess, and when there is too little a method of supplying the deficiency. By using Lake Okeechobee as a reservoir and the drainage ditches or canals for distributing the water this can be readily accomplished. There will be no necessity for expensive pumping plants, but with suitable gates the level of the water can be regulated in the ditches to supply the crops by the ordinary methods of subirrigation at a comparatively small cost. Few places are as favorably located for both drainage and irrigation as the country lying south of Lake Okeechobee.

HEALTHFULNESS AND TRANSPORTATION FACILITIES.

The climate of the Everglades is subtropical. The long summers produce a feeling of lassitude and are extremely irksome, especially to persons accustomed to a northern climate, but do not impair the health or cause disease. Mr. Brown, the proprietor of the store on the west border of the Everglades, has reared a family at that place without serious sickness among its members. The workmen on the State dredges have as good health as those engaged in similar work in the Northern States. The members of the party who made the survey across the Everglades in 1907–8 drank the water of the Everglades without discomfort or injurious effects. It should be noted, however, that the trip was made during the winter, when the climate is more agreeable than at any other season. There are mosquitoes in every part of the Glades, and while not particularly troublesome during the day they swarm in myriads about sundown, making it necessary for the traveler to seek protection behind a substantial mosquito netting.

Dade County, in which the Everglades are situated, has an area of 4,424 square miles and (in 1900) a population of 4,955. The Florida East Coast Railroad, running from St. Augustine to Miami, near the Atlantic coast, furnishes at present the most convenient facilities for reaching the Glades. The stations on this line directly east of the Glades are Miami, Fort Lauderdale, West Palm Beach, and several other smaller shipping stations. Beyond a distance of 1 or 2 miles west of the railroad there are no settlers, except a few truck farmers in the vicinity of New River. From the settlements along the railroad there are numerous wagon trails leading out in the direction of the Everglades, but terminating at the edge of the swampy ground. The only way of entering the Glades from these points is by wading or by small push boats, such as have been described in a previous part of this report.

The only town on the west side of the peninsula from which the Glades can be reached is Fort Myers, the county seat of Lee County, on the Caloosahatchee River. It is reached by the Atlantic Coast Line Railway and by boats of shallow draft from the Gulf. It had a population of 1,500 in 1900 and is a distributing point for the entire Caloosahatchee Valley. The only way of reaching the Ever-

glades from this city is by boat up the river to Lake Okeechobee or by a drive of 70 miles over sand roads and through sloughs to the west side of the glades in the vicinity of Brown's store.

It does not come within the province of this bulletin to discuss all the various phases of this reclamation project. Among these are the sale and colonization of the vast area, the canvass of the world's markets for disposing of the products that can be grown, the speculative value of the lands, and numerous other important matters which are closely interwoven with every land-development project.

Attention, however, may be called to several points which should be helpful to those who have the reclamation of the Everglades under consideration. The feasibility and general plan of draining these lands have been pointed out and also the characteristics of the soil and its possibilities, though it should be understood that the latter are largely undetermined.

The effect of permanently lowering the water in Lake Okeechobee, which is an essential part of the plan to drain the Everglades, will beneficially affect a zone of land on the north side of the lake and the lower part of the Kissimmee Valley.

After the muck lands have been drained a settlement of the surface will probably take place equal to about one-half of the depth from the present surface to the permanent water table, the amount varying with the compactness of the muck.

While the absence of silt and clay in the vegetable matter and the presence of an underlying sand and rock foundation instead of clay, detracts from the lasting qualities of the soil, the latter makes it possible to erect needed buildings and other structures upon a secure foundation.

First-class roads can be made in the glades after drainage by using the underlying rock, which can be quarried at convenient points in the Glades, the value of which for this purpose has been demonstrated along the east coast. Ordinary public and farm roads can be made by covering the muck with sand, which makes the surface sufficiently compact for road use. Roads are made in this manner through the reclaimed moor lands of Germany wherever they are underlaid with sand or rock.

The following is presented as a brief summary of the results of the investigations in the Florida Everglades, with reference to their reclamation for agriculture:

SUMMARY.

The upper Everglades comprise an area of approximately 1,850,000 acres, lying south of Lake Okeechobee, and is the only part in which the depth of the muck will warrant the expense of reclaiming.

The high-water stage of Lake Okeechobee is 22 feet and the low-water stage is 19 feet above mean sea level. The surface of the land at the south border of the lake is 21 feet and at a point 30 miles south of the lake is 13 feet above sea level.

The depth of the muck for several miles south of the lake is from 7 to 15 feet. Along a line across the Glades easterly from Brown's store the muck varies from 2 to 6 feet deep, with occasional points where the rock crops out upon the surface. The entire area is underlaid with porous or shelly lime rock, upon which, in many places, is a covering of sand.

As far as can be ascertained, the quality and fertility of the muck south of the lake is the same as the saw-grass muck of the Kissimmee River Valley, and that at St. Cloud, in Osceola County, where sugar cane and truck crops were successfully grown by the Disston Land Co. (so called) from 1893 to 1898, and also at the United States experiment station at Runnymede. The depth and compactness of the muck found in different parts of the Everglades are not uniform.

The drainage of the land by means of gravity canals and controlling gates is feasible. The plan recommended consists of main canals approximately 8 miles apart, leading from Lake Okeechobee southeasterly to the Atlantic Ocean, one of these canals to be for navigation in connection with the improvement of the Caloosahatchee River by means of which boats may pass from tide water on either side into Lake Okeechobee.

The plan proposed provides for the control of the water of Lake Okeechobee and of the main canals required to drain the Glades. The laterals and other interior drains which will later be required in the complete reclamation of the land for agriculture are not indicated.

BENCH MARKS.

The following bench marks were established by the United States Department of Agriculture:

Location, description, and elevation of bench marks.

Bench mark.	Location and description.	Elevation.
	West coast.	
		Feet.
No. 1	Fort Myers, Heitman's grocery store, corner First and Jackson Streets: Raised part of iron plate at corner of brick, under Jackson Street window.	7.68
No. 2	Fort Myers, Buckingham's store, marked "Warehouse": Cross on east doorsill	14.97
No. 3	Fort Myers, north side of lane to Goodno Dock: Nail in root of blazed oak tree	12.09
No. 4	Travers House, 300 feet north of pens: Nail in root of blazed pine tree	25.43
No. 5	Immokalee road, east of Kenneday Carson's house: Spike in root of pine tree	24.90
No. 6	Immokalee, 100 feet northwest of schoolhouse: Spike in root of pine tree	38.07
No. 7	Glade Cross Road, one-half mile west of Leaning Oak: Spike in root of palmetto	26.54
No. 8	Rock Lake, west side: Spike in cypress tree	24.65
No. 9	Glade Cross Mission, south side of hammock near cottage: Spike in palmetto	17.86
No. 10	Brown's store, edge of boat trail: Top of iron wagon axle driven into sand.	17.25
	East coast.	
No. 1	West Palm Beach, city dock: Top of tide gauge	3.70
No. 2	Riviera Station: Cross on middle brick pier	16.55
No. 3	Section corner ¼ ¼ T. 43 S., R. 42 E.; 33 feet west: Nail in root of blazed pine	19.46
No. 4	Government road, east side below Lantana truck farms: Nail in root of blazed pine	19.50
No. 5	Government road, west side, one-fourth mile north of Hillsboro cypress: Nail in root of small blazed pine	15.83
No. 6	In Everglades at end of staked Hillsboro line of State dredge ditch survey: Cypress butt squared up and marked thus: On east side, "U. S. B. M.;" on south side, "Elev. 17.4;" on north side, "Sta. 57+130"	17.39
No. 7	East beach of Lake Okeechobee at entrance of Loxahatchee-Okeechobee line: Nail in notch of big cypress tree	23.40
No. 8	Loxahatchee-Okeechobee line, about Station 265+250: Nail in root of blazed pine tree	25.23
No. 9	Loxahatchee-Okeechobee line, near Station 192: Nail in blazed cypress tree	26.90
No. 10	Loxahatchee-Okeechobee line, near Station 89: Nail in blazed pine tree	24.26
No. 11	Loxahatchee River Bend known as "Cowhead," just south of Station 0+350 and 350 feet from bend: Nail in root of blazed pine	13.97

Datum, mean sea level.