2. 1954

In response to the very wet years prior to 1954, particularly the fall of 1953, Figure 3-2 (which follows the text), a new schedule was put into effect in May 1954 in an effort to offer a higher degree of flood protection. It had maximum discharges through the Caloosahatchee River while water levels were in Zone B. Other features that increased the flood protection afforded by this schedule were the earlier spring decline of the lower schedule and the lower elevation of the upper schedule in the summer and fall months. It may be assumed that the absence of Zone B during the period between November 15 and February 1 was incorporated to increase the water supply for spring water use requirements.

3. 1958

In 1958, refinements were made to the schedule adopted in 1954, which are illustrated in Figure 3-3, following the text. These refinements were made in an effort to reduce the overall flow to the St. Lucie Canal during the wet season and also attempted to prevent erosion within the St. Lucie Canal by limiting the velocity of flow through the St. Lucie Canal when possible. The second schedule evaluated was a seasonal 15.5-16.5 ft., NGVD schedule which because of its one foot zone of variable releases became known as the 15.5-17.5 ft. NGVD schedule. This schedule was approved by the Chief of Engineers in Part IV, Supplement 2, Section 7, dated 25 February 1959. It was determined that the 15.5-16.5 ft. NGVD schedule would provide the same level of irrigation benefits as the flat 16.4 ft. NGVD schedule. This report pointed out that large additional benefits could be obtained from sufficient conservation storage in Lake Okeechobee to supply the need of urban areas along the coast during droughts. In addition, this schedule would provide seasonal flood control storage which would help minimize damages caused to estuaries by large regulatory releases.

4. 1965

In 1965, the regulation schedule was modified to allow storage to accumulate during the wet season. This was in response to the dry conditions of the early 1960's and particularly the dry spring months of the same year so that water could be stored for water use purposes. This schedule, Figure 3-4, which follows the text, was only in operation for the summer and fall of 1965. This was one of the first schedules put into operation that did not have the lowest point of the schedule immediately prior to the peak of hurricane season.

5. 1966

The schedule put into operation in January 1966 was derived primarily in accordance with an interagency agreement to deliver water to the ENP. This schedule is illustrated in Figure 3-5, following the text.

6. 1972

In 1972, Zone C was discontinued and the lowest level on Zone B was raised one-half of one foot in an attempt to increase water supply. This schedule along with its operational rules appears in Figure 3-6, which follows the text.

Due to the extended dry period in the early 1970's, and increased water use requirements of the lake, the levee system surrounding the lake was improved so that the lake could safely be regulated between 15.5 ft. and 17.5 ft., NGVD. While work was nearing completion in 1974, an interim schedule was put into operation to raise the schedule one-half foot to a range between 14.5 and 16.0 ft., NGVD. The 15.5 to 17.5 ft. NGVD schedule went into operation in the summer of 1978.

7. <u>1978</u>

The 1978 schedule increased the range of water levels over which the lake is operated from 14.5-16.0 ft., NGVD, to 15.5-17.5 ft., NGVD. This regulation schedule was created in an effort to store a greater amount of water, available during the wet periods, for use during subsequent extended dry periods. During the period between 1960 and 1978, the lake experienced several extended periods during which rainfall amounts remained precariously low. The available water supply stored in the lake was stressed several times during this period, particularly in 1971 and 1974. In addition, with the projected increase in water use requirements of the service areas surrounding the lake and those of the LEC, it was estimated that the situation might get worse in the future. The 1978 schedule defines three zones as shown in Figure 3-7, which follows the text. A brief description of those zones is provided below.

(a) <u>Zone C</u>

The bottom zone, Zone C, is characterized by an upper limit between 15.5 and 17.5 ft., NGVD. These levels define the conservation pool and they reflect the maximum desirable water surface elevations for Lake Okeechobee. When the lake stage is within Zone C, SFWMD allocates water to various users. The only other releases are related to navigation.

(b) <u>Zone B</u>

Zone B extends one foot above Zone C and it defines lake level conditions under which moderate regulatory releases are made from the lake to the St. Lucie and Caloosahatchee estuaries. Due to problems associated with large releases, discharges are limited to 2,500 cfs into St. Lucie Canal and 4,500 cfs into the Caloosahatchee River. The major problems associated with larger discharges are related to sedimentation and disruption of favorable salinity regimes in the estuaries.

(c) <u>Zone A</u>

Zone A lies above Zone B, and it corresponds to the maximum, safe release of floodwaters from the lake. This zone defines the point at which up to maximum regulatory releases are initiated through all of the lake's outlets. Those discharges should be maintained until the lake level recedes to a point in Zone B. While a Zone A condition does not necessarily imply the existence of flooding due to excess water in the lake, it is very important that the lake level be reduced quickly to provide adequate storage capacity for the next possible flood event. The reduction in lake level is directed primarily at relieving levee stress and erosion, and at reducing detrimental impact on the lake's littoral zone.

8. Run 25

In May 1992, an alternative regulation schedule, RUN 25, was put into effect for a two year period (Figure 3-8). The RUN 25 schedule ranges from 15.65 to 16.75 ft. NGVD, with multiple operation zones that vary flood releases over a wide range before reaching maximum release rates. The purpose of the 15.65 to 16.75 ft. NGVD regulation schedule is to reduce damaging flows to the St. Lucie Canal and Caloosahatchee River estuaries without sacrificing the flood control or water supply benefits derived form the lake. The two year test period was extended for three months. RUN 25 was approved for implementation in December 1994 as the Interim Schedule.

b. Proposed Schedule Modifications

In 1968, Public Law 90-483 included authorization for raising the Lake Okeechobee regulation schedule to range between 19.5 and 21.5 ft., NGVD. The primary reason for consideration of such a change is related to the increasing water supply demands which accompany the continuing development of south Florida. The modified regulation schedule would allow lake storage of additional water to satisfy those demands. The authorized schedule increase would include a maximum conservation pool (Zone C) ranging from 19.5 to 20.5 ft., NGVD. Zone B would consist of an additional one foot increase above Zone C; therefore, moderate regulatory releases would be made when lake levels ranged from 19.5 to 21.5 ft., NGVD. Regulatory releases, up to the maximum allowable, would be initiated at all lake outlets when the lake level exceeded 20.5 to 21.5 ft., NGVD. Presently, there are no plans to raise the lake regulation schedule in accordance with these proposed modifications.

c. Further Studies

At the request of the local sponsor, the SFWMD, and Governor Lawton Chiles, the Jacksonville District has initiated a regulation schedule review study. The purpose of the study is to determine if a more ecologically beneficial schedule exists which simultaneously meets the C&SF Project objectives. The study will be subject to a thorough environmental impact analysis and quantification of economic issues associated with implementation of a revised schedule.

3-06. Principle Regulation Problems

a. Gap at Florida East Coast Railraod (F.E.C. RR) in St. Lucie Canal Tieback Levee

Gaps were left in the tieback levees where the F.E.C. RR crosses the St. Lucie Canal about one mile east of Port Mayaca. The low point of the gaps are approximately at elevation 24.5 ft., NGVD. These gaps preclude full use of the 14,800 cfs SPF design capacity of the St. Lucie Canal until the railroad is notified to cease operations, and the railroad bridge span is lifted. The F.E.C. RR should be notified to suspend train operations 24 hours in advance of tailwater elevations which will exceed the bottom chord of the railroad bridge at the St. Lucie tieback levee (elevation 20.5 ft, NGVD). Flood levels may also require the sandbagging of gaps in the tieback levees.

b. FP&L Martin Reservoir

The west dike of the FP&L cooling reservoir is only a few yards east of L-65 Borrow Canal. To preserve the stability of this dike, which failed in 1979, it is essential to maintain the water level in L-65 Borrow Canal as near optimum level as possible. SFWMD, with Corps permission, modified the gates at S-153 by splitting the gates approximately in half. The lower half remains detached from the upper half until the whole gate needs to be opened for flood control. This precludes total accidental drawdown of the borrow canal, or deliberate drawdown in the case of vandalism as occurred only hours before the FP&L dike failure in 1979. In addition, FP&L reservoir operators are required to notify the Corps Port Mayaca Lockmaster before commencing spillway or pumping operations.

c. Water Quality in Lake Okeechobee

Since significant water quality measurements were first documented in 1970, the phosphorus concentrations in Lake Okeechobee have increased steadily. There is some correlation between high lake stages and high phosphorus concentrations, but phosphorus loading from external sources is the main reason for the increase. Florida Department of Environmental Protection (FDEP) and SFWMD have instituted measures to reduce the phosphorus loading to the lake. The Interim Action Plan (IAP), instituted by SFWMD in 1979, and formalized in the Lake Okeechobee Operating Permit (LOOP), has resulted in a 90 percent reduction in water backpumped to the lake through S-2, S-3, and S-4. Part of the IAP is a point system which considers more factors than just the amount of water on the ground (i.e., stage). It considers stage, rainfall amount, forecast, and rate of rise in the canal. Water quality is of such great concern that emergency backpumping for water supply is rarely done by SFWMD.

d. Regulation Capacity at S-77

The design capacity required for S-77 is 9,300 cfs for all floods up to the SPF. There is a problem in that the stilling basin was not designed to dissipate the energy for the higher lake stages. As a result, the maximum safe discharge at a lake stage of 16.5 ft., NGVD is about 8,900 cfs. This diminishes to about 6,500 cfs at the SPF stage of 25.1 ft., NGVD.

e. Algae Blooms in the Caloosahatchee River

During the seasonally dry months from December to April of each year the Caloosahatchee River flow diminishes to the point that an occasional severe algae bloom develops in the river above Franklin Lock and Dam. The City of Ft. Myers and Lee County both have municipal water intakes in this area which could be clogged by the algae. Short term high rates of discharge from Lake Okeechobee are required to break up the algae bloom. This is done by the Corps whenever requested by the SFWMD.

f. Salinity Intrusion at Caloosahatchee River

During the extreme dry months of April and May, the Caloosahatchee River flow may drop to near zero. When this condition prevails, navigation lockages through the W.P. Franklin Lock allow a salt water wedge to move upstream. More lockages result in more salt water moving upstream. Eventually, the chloride content of the water entering the municipal water intakes of Ft. Myers and Lee County exceeds the drinking water standard of 250 milligrams per liter (mg/L). When this happens, SFWMD requests the Corps to flush out the salt water with a short term high rate of discharge from Lake Okeechobee. During a declared water shortage period the SFWMD requests the Corps to go to reduced hours of lockages.

g. S-169 Capacity

SFWMD permitted more surface water connections than the capacity of S-169. The SFWMD obtained a permit from the Corps to enlarge S-169 from three culverts to four. This has largely reduced the design capacity shortfall. However, the operational strategy to fully open the structure in advance of a hurricane has continued, leaving Industrial Canal to fluctuate with the control level maintained by S-4.

h. Bank Erosion St. Lucie Canal

1. General

The St. Lucie Canal was excavated by dredge in the early 1900's by a drainage district authorized by the State of Florida. The canal was excavated through sandy soils throughout its length resulting in nearly vertical banks. The Corps subsequently deepened the canal using similar dredging techniques. Regulatory discharges from Lake Okeechobee and boat wakes have been frequent enough to prevent natural bank stabilization. Some areas have already eroded beyond the right-of-way line and other areas are endangered.

2. Bank Stabilization

Bank stabilization measures are needed particularly west of Indiantown. It is especially critical to protect the North Tieback Levee of St. Lucie Canal near Lake Okeechobee because this is where canal water levels are highest and land elevations are lowest. The CESAJ recently completed the St. Lucie Bank Stabilization and Restoration of Rights-of-Way Letter Report. This report concluded that the long term solution for the bank stabilization problems should be incorporated under the C&SF Project Comprehensive Review Study authorization.

3. Minimum Headwater at S-80

During regulated maximum flood releases the minimum headwater elevation at St. Lucie Spillway (S-80) shall be operated no lower than 10.0 ft., NGVD for lake stages up to 18.5 ft., NGVD. This is to help reduce erosion upstream of the dam due to high velocities.

i. Protection Grade at S-84 and S-65E Lock

The maximum wind induced tide that can be blocked by S-84 is 25.0 ft., NGVD. The maximum at S-65E navigation lock is 28.5 ft., NGVD. The wind tide used for design of the Kissimmee River (C-38) tieback levees (L-D4 and L-48) was 27 ft., NGVD. This places a requirement on the S-84 tieback levees along C-41A that Corps and SFWMD regulatory programs should recognize in all future drainage applications in the area.

j. SR 78 at Fisheating Creek

A letter report was issued in 1978 recommending raising the elevation of S.R. 78 inside the embankments at Fisheating Creek to above a 19.5 ft. NGVD lake level plus two and one-half feet, for a crest elevation of 22.8 ft. NGVD. This appears to be based on a 50-year event, but additional research may be necessary to determine the actual as-built road elevation and current stage-frequency information.

k. Development Inside the Lake

There are temporary and permanent structures inside the Lake, including Belle Glade Marina and Campground on Kreamer Island, and Okee Taintee Recreation Area by the Kissimmee River. These areas, including S.R. 78, could conceivably be flooded by either high lake levels or storm surge events.

l. Tieback Levees to Pump Stations at Culvert Structures C-4A, C-10, and C-12

The levees at C-4A and C-10 are built only to elevation 20 ft. NGVD +/-, and to elevation 24 ft. NGVD at C-12 (with a low spot to elevation 18 ft. NGVD by the pump house). This limits the lake level that these structures can pump against since the water has to flow through the flap gates back into the Lake.

Table 3-1
Chronology of Events

- 1850-The Swamp and Overflowed Land Grant Act of 1850 vested title to the Everglades to the State of Florida, on conditions that proceeds of their sale be applied to reclamation of lands. The area received immediate consideration by agricultural interests due to its fertile lands and mild winters.

- 1855-The State Legislature created the Trustees of the Internal Improvement Fund to administer the overflowed lands.

- 1881-The first contract for construction of drainage canals was awarded in 1881, but little actual progress was made until 1902.

- 1905-The Legislature created the Everglades Drainage District to further reclamation work. This led to more extensive operations which began in 1906 and continued to 1929, when work practically ceased due primarily to depletion of funds.

- 1912-Everglades Drainage District began recording lake stages and rainfall amounts.

- 1926-Hurricane struck on 18 September 1926. 386 lives were lost at Moore Haven. Property damages were estimated at $6,000,000.

- 1928-Hurricanes struck on 16 September and 28 November 1928. Approximately 2,700 lives were lost. Property damages were estimated at $75,000,000.

- 1930-The River and Harbor Act of 3 July 1930 included a navigation and flood control project for the CR&LODAs. Features included construction of:

  a. Caloosahatchee Canal and River improvements
  b. Taylor Creek improvements.
  c. Levee and navigation channel along south shore.
  d. Levee along north shore.
  e. St. Lucie River improvements.
  f. Protective works in St. Lucie Canal.

- 1932-Actual levee construction began on 6 January 1932. The south shore levee system from Fisheating Creek to St. Lucie Canal was completed on 21 March 1936.

- 1933-Hurricane struck 3 September 1933. Uncompleted levee at Bacom Point was severely eroded but not breached. No loss of lives was reported.

Table 3-1 (Continued)
Chronology of Events

- 1935-The River and Harbor Act of 30 August 1935 provided that the U.S. maintain and operate all project works when completed. (This is not correct, maintenance was turned over to local entities in 1930?)

- 1935-A Federal measurement system for collection of meteorological data was initiated in the mid-1930's.

- 1936-North shore levee construction began 22 July 1936 and was completed 3 February 1938.

- 1947-Two hurricanes and related flood conditions caused flood damages estimated at $60,000,000; however, there was no loss of life.

- 1962-Construction of L-48, L-49, and L-50 levees on the northwest shore was completed.

- 1965-L-47 levee construction on the northeast shore began in August 1965 and was completed in November 1967.

- 1965-Construction associated with raising levees L-D1, L-D2, L-D3, L-D4, L-D9, and L-52 was completed.

- 1966-Completed construction of spillway (S-77) at HGS-1.

- 1973-Completed HGS to lock conversion at HGS-6 (S-193).

- 1980-Completed HGS to lock conversion at HGS-2 (S-310).

- 1986-Revetment Contracts 2 (N. West Palm Beach Canal and Liberty Point) and 4 (Bacom Point) were completed.

- 1987-Revetment Contract 6 (west of Clewiston) was completed.

- 1988-Revetment Contract 1 (south of Port Mayaca and at Pahokee State Park) was completed.

- 1989-Revetment Contract 3 (Port Mayaca and Nubbin Slough) was completed; also completed HGS to spillway conversions at HGS-4 (S-351) and HGS-5 (S-352).

- 1990-Completed HGS to spillway conversion at HGS-3 (S-354).

-

IV-WATERSHED CHARACTERISTICS

4-01. General Characteristics

Lake Okeechobee lies about 30 miles from the Atlantic coast and 60 miles from the Gulf of Mexico. The large, roughly circular lake, see Plate 2-1, with a surface area of about 700 square miles, is the principal natural reservoir in southern Florida. The drainage area, including the lake area, is about 5,600 square miles. OWW is 154.6 miles long and eight feet deep from Ft. Myers to the Intracoastal Waterway, Jacksonville to Miami, near Stuart. It is 90 feet wide from Ft. Myers to Moore Haven, a distance of 56.5 miles; 80 feet wide along the south shore of Lake Okeechobee as far as the hurricane gate at Clewiston, a distance of 13 miles; 100 feet wide from Clewiston across the lake and in St. Lucie Canal to the St. Lucie Lock, a distance of 49.9 miles, and 80 feet wide from St. Lucie lock to the Jacksonville-Miami waterway, a distance of 15.1 miles.

Principal tributary streams are: Kissimmee River, Fisheating Creek, Indian Prairie Canal, and Harney Pond Canal. The largest outlets from the lake to the Gulf of Mexico and Atlantic Ocean are channels to the headwaters of the Caloosahatchee River and the St. Lucie Canal, respectively, which have been constructed to afford a continuous navigable channel across the state and to provide control of lake levels. The four major agricultural canals, West Palm Beach, Hillsboro, North New River, and Miami Canals, have a smaller capacity, but are used whenever possible to release excess water to the WCAs south of the lake when storage and discharge capacity are available. Much of Lake Okeechobee is very shallow, and the deepest parts extend only to about mean sea level. The waters of the lake are impounded by a system of levees which form a multi-purpose reservoir for navigation, water supply, flood control, and recreation. The lake is regulated on an interim seasonal schedule ranging from 15.65 to 16.75 ft. NGVD. Storage provided under that seasonal regulation schedule is as follows: Conservation storage, 2,946,000 acre-feet; flood control storage, 3,641,000 acre-feet; and seasonal dual-purpose storage, 600,000 acre-feet. The minimum area dependent on Lake Okeechobee is about 1,850 square miles, of which about 60 percent is in agricultural production. This includes primarily the Lake Okeechobee agricultural area plus other areas around the lake and along St. Lucie Canal. There is a potential agricultural service area of over 3,400 square miles.

The Fisheating Creek area is about 50 miles long, drains a watershed of about 540 square miles, and is swampy and generally undeveloped. Elevations range from over 100 feet in the high, sandy ridge in the northwest to 15 feet at Lake Okeechobee. Lake levees tie back on either side of the Fisheating Creek flood plain, leaving this the only uncontrolled inflow to Lake Okeechobee.

The Northwest-shore tributary area consists of a strip of land, approximately 61 square miles, which borders the lake from Fisheating Creek to the Kissimmee River. It is completely surrounded by project levees, which also isolate it from Indian Prairie and Harney Pond Canals which pass through it. It is drained by three project pump stations. The area is used primarily for native and improved pasture, with a few small subdivisions of vacation and weekend cottages.

The Northeast-shore tributary area borders the north and northeast shores of the lake including about 270 square miles extending from Kissimmee River to St. Lucie Canal. All inflow from this area is controlled by pump stations and locks in Levee 47. The largest stream in this area is Taylor Creek, which drains the 150 square mile portion north of the lake. The area is used almost exclusively for cattle grazing, although some residential communities exist in addition to the city of Okeechobee, which is one of the larger urban areas on the north side of the lake.

The St. Lucie Canal watershed between Lake Okeechobee and St. Lucie Lock comprises an area of about 170 square miles which is highly developed in citrus, vegetables, and improved pasture. Inflow to the canal is through a number of government-built spillways and private pumps and spillways built under permit.

The Southshore area consists of 420 square miles of agricultural area between the Caloosahatchee River and Bacom Point. Three project pump stations discharge the excess water directly into Lake Okeechobee; S-2 from the North New River and Hillsboro Canals, S-3 from the Miami Canal, and S-4 in the vicinity of Clewiston. In addition, drainage district private pumps can discharge through ten government-built culverts in the levees. The West Palm Beach Canal drains to WCA No. 1. Between WCA No. 1 and the St. Lucie Canal, an additional five culverts can discharge to the lake.

The Agricultural Area comprises lands located immediately south and southeast of Lake Okeechobee. This area of about 1,130 square miles is rich, fertile agricultural land, well suited to long-term productive use. The average ground elevation is about 12 feet. The general soil types near the southeastern shore of Lake Okeechobee are Okeechobee muck and Okeelanta peaty muck; Everglades peat and peaty muck are found farther south. Crops usually grown in the agricultural area are sugarcane and truck crops, including beans, celery, cabbage, tomatoes, and peppers. The area is encircled by levees to protect against floodwaters; a network of canals, structures, and levees divides the area to provide for removal of excess water to Lake Okeechobee and the conservation areas and for delivery of water from Lake Okeechobee for dry-season use.

The Caloosahatchee River Basin encompasses parts of Lee, Glades, Charlotte, and Hendry Counties. It is bounded on the west by the Gulf of Mexico, on the north and northeast by the Peace River and Fisheating Creek watershed, on the east and southeast by Lake Okeechobee and the Devil's Garden area of the Everglades region, and on the south by the cypress swamps of the Everglades. The drainage area is about 1,245 square miles. The watershed length is approximately 63 miles from Lake Okeechobee to the Gulf of Mexico, the maximum width is 35 miles, and the average width is 20 miles. Elevations range from 78 ft. NGVD on the north to about 40 ft. NGVD on the ridge south of the river. Generally, the slope of the terrain ranges from very flat lands in the vicinity of Lake Okeechobee to about two and one-half feet a mile for the area north of the river. This northern area is fairly well drained by the many creeks and runs that extend from the river toward the uplands. South of the river, the land slopes perceptibly for several miles from the river, but then flattens to slopes of less than one-half foot a mile. The area contains numerous sloughs and swamps, and the drainage is very poor. Flooding on those lands occurs almost annually and lasts for several months during the wet season.

4-02. Topography

The area south and southeast of the lake consists of 1,120 square miles of rich agricultural land. Under natural conditions, it was the northern end of a grassy marsh lying in a trough of sedimentary lime rock. The entire marsh area is about 40 miles wide and extends south about 100 miles from Lake Okeechobee to the tip of the State. It is bordered on the east by a narrow coastal ridge which rises to elevations of 12 to 20 ft. NGVD, separating the Atlantic coastal drainage. On the west the boundary is a ridge of sandy ground rising to an elevation of about 25 ft. NGVD Continuous growth and decay of vegetation over long periods of time has resulted in the deposit of peaty muck which now composes the soils of the Everglades. Present general elevations of those muck lands average about 12 ft. NGVD at Lake Okeechobee to about six or seven ft. NGVD at the latitude of Miami. In its former natural state, Lake Okeechobee had no well-defined outlet. During flood stages its rising waters would spread over the area to the south, or spill slowly into the flat areas west of the lake and find their way to the Caloosahatchee River. The major portion of the discharge is believed to have been through the Everglades to the south.

Since 1900, natural ground ranged from 18 ft, NGVD near the lake to 8 ft., NGVD at the elevation of Tamiami Trail. However, draining and farming operations in the agricultural areas have brought about oxidation and shrinkage of the peat and muck soils to the extent that the north side of the agricultural area is now several feet lower than before. The Caloosahatchee valley area west of Lake Okeechobee varies in elevation from zero to about 40 ft., NGVD. The St. Lucie Canal area east of the lake varies in elevation from 10 ft., NGVD near the St. Lucie Lock to about 30 ft., NGVD near the lake.

4-03. Geology and Soils

The project area occupies the southeastern part of the Floridian Plateau. The oldest rocks encountered in deep oil test wells drilled to over 10,000 feet in the area are limestone of the Lower Cretaceous age. Metamorphic and igneous rocks of Triassic and Paleozoic age probably underlie the cretaceous limestone as they do in the northern part of the state. The rock lying below the Miocene Hawthorn formation is predominantly Upper Cretaceous and Lower Tertiary limestone, suggesting that Florida was long remote from sources of clastic sediments. The presence of marls, sands, and sandy limestone in the Upper Tertiary and Quaternary systems indicates a shallow-water environment with a source of clastic sediments. Except for intervals of freshwater limestone and marl deposition during Pleistocene time, and freshwater marl and organic soil deposition during recent time, all deposition has been under the influence of a marine environment. Coastal movements beginning in late Eocene and continuing into late Niocene time produced a broad, elongated arch trending and plunging in a southeasterly direction west of the Everglades area in southern Florida. The domal portion of the arch is centered in Marion County where the late Eocene Ocala limestone is at or near the surface at an elevation of about 150 feet. Flanking the Ocala limestone as it dips under them are younger formations of Oligocene and Miocene age overlain by Pliocene and Pleistocene beds. The latter formations slope away from the structure dome a few feet a mile, and generally thicken seaward. In the region covered by this report, limestones, sandstones, marls, and sands of Miocene, Pliocene, and Pleistocene age generally slope and thicken to the east away from the axis of the arch. The sediments have a total thickness of well over 100 feet.

Soils in the area consist primarily of one or more basic materials; namely, peat, muck, sand, and clay. Unusual characteristics of peat and muck include water holding capacity, which may run as high as 800 percent; shrinkage and loss of weight on the order of 75 to 80 percent on drying; and specific gravity as low as 1.5. The sands in the area appear to be typical fine to medium uniform sands. It is assumed they will approximate similar sands which have been found to have an average in-place density of 95 pounds per cubic foot and an angle of internal friction of 29 degrees. No general description of the soils can be made for the entire project area because of the heterogeneous nature of the material. Accordingly, in the design of the project works, individual studies were made on sites and alignments.

4-04. <u>Sediment</u>

Data concerning Lake Okeechobee sediments were virtually non-existent prior to 1974. An unpublished paleolimnology study of lake sediment cores conducted by Gleason and Stone (1975) identified four basic sediment types: quartz sand found principally along the west and northwest shore, rock and unconsolidated marl extending from the south end of the lake (near Rocky Ridge) east and northeast to Chancey Bay, peat sediments located along the south and southeast shore extending from Clewiston to Pahokee (including Kreamer, Torry, and Ritta Islands), and copropelic muds extending from the Kissimmee River and S-191 (Taylor Creek/Nubbin Slough) south to the east central portion of the lake. Surface layers of this mud are composed of a fine flocculent material which is easily resuspended in the water column by wind driven waves causing the lake's characteristic high turbidity levels.

Peat sediments were highest in organic content (63-81 percent) followed by copropelic mud (40 percent) and sand (>1 percent organic). Peat sediments also contain the highest average nitrogen content on a dry weight basis (2.4 percent) as compared to mud (0.8 percent) and sand (>0.1 percent). In contrast, copropelic muds exhibited the average highest phosphorus content (0.089 percent) as compared to peat (0.043 percent phosphorus) and sand (.019 percent phosphorus). Examination of mud cores showed these sediments to contain high concentrations of interstitial orthophosphorus and ammonia.

Paleolimnological analysis of sediments concluded that the lake was moderately eutrophic at least 4,700 years ago. The lake's soft copropelic sediments were found to contain microfossil (diatoms and sponges) indicator organisms characteristic of eutrophic lake conditions.

The predominant soils within the agricultural area are muck and peat. Peat soils contain 65 percent or more organic matter, much of which is often only partially decayed. Muck soils contain from 25 to 65 percent organic matter mixed with mineral matter. The peat, in its natural state, weighs only 63 to 65 pounds a cubic foot. When dried it loses about two-thirds of its volume and over three-fourths of its weight. The soils were formed during the periods when the area was more or less permanently wet. Drainage of either muck or peat results in shrinkage by removal of moisture and by oxidation. There is also danger of destruction by fire when peat and muck areas are drained. The deep peat in the northern Everglades, which has been cultivated and drained, has subsided as much as five feet since earliest drainage. The muck, probably because of its higher percentage of mineral matter and more completely digested organic matter, appears to subside only about half as much as the peat. Experiments conducted by the Everglades Experiment Station have shown that the higher the water table, the lower the rate of subsidence. Thus, that relationship is an important consideration in the reclamation and use of the peat soils. Since water requirements of such lands are affected by the depth at which the water table is to be maintained, a balance is necessary which takes into account available water supply, type of crop to be produced on the soil, and rate of subsidence. A dependable water supply is necessary during dry seasons and droughts to maintain a high water table and thereby prevent rapid subsidence.

4-05. Climate

Lake Okeechobee is in a transition zone between tropical and temperate climates, and is greatly influenced by proximity to the Atlantic Ocean and, to a lesser degree, to the Gulf of Mexico. High humidity accompanies high temperature which promotes excessive water loss by evaporation and transpiration from lakes, swampland, vegetation, and the nearby Atlantic Ocean and Gulf of Mexico. Strong convection currents result from uneven heating of the atmosphere over different types of soil and vegetative cover. Such heating is most noticeable over black muck soils which are exposed by cultivation, causing great quantities of moisture laden air to be carried aloft, far beyond condensation level. That process results in the occurrence of almost daily thunderstorms in the same general area during the summer months.

a. Temperature

Temperatures are moderately high from June through September, and pleasantly cool from November through April, without the extremes that occur in interior portions of the United States. Although record temperatures have ranged from 19 to 103 degrees Fahrenheit, such extremes rarely occur. Annual mean temperatures range from approximately 72 to 75 degrees Fahrenheit over most of the area, with January mean minimums mostly between 49 and 59 degrees Fahrenheit, and August maximums mostly between 89 and 93 degrees. Sunshine is high throughout the year, relative humidity is generally moderate-to-high, and winds are generally light-to-moderate, but occasionally destructive.

b. Precipitation

Wet and dry seasons are well defined as occurring from June to September and from November to April respectively with May and October as transitional months. Historically, wet season precipitation results from convective and tropical storm systems while dry season rainfall results from frontal systems. Annual rainfall averages about 52.0 inches over the project area, see Table 4-1. Of that rainfall, only about 25 percent occurs during the six months of November through April and about 75 percent occurs during the wet period, May through October.

Table 4-1
Representative Climatological Station Annual Precipitation

Station	Average Annual Precip* (Inches)	Period of Record
Belle Glade	55.17	1924-1993
Clewiston FS	47.13	1948-1993
Moore Haven	47.98	1930-1993
Stuart	57.50	1948-1993
Mean	51.95	

* National Climatological Data Center Summary of the Day, data on a compact disk read only memory (CDROM). Data is average for period of record at each gage based on years with no missing data.

The following is a brief discussion of typical types of rainfall-producing patterns identified over Florida:

1. Isolated air mass. Local convective showers due to daytime heating. Generally, if rain occurs it is limited to a small area and short duration.

2. Sea Breeze. Sea breeze generally occurs on undisturbed days during the warm months. Associated showers form along the coast and move inland during the day. There are many types of disturbance including cold air aloft and weak cyclonic flow.

3. Sea Breeze and Disturbances. If sea breeze is associated with a larger scale disturbed pattern, more widespread rain is possible.

4. Meso-scale Thunderstorms and Showers. These systems are often perturbations along old frontal troughs. Meso-scale shower and thunderstorms are quite common over Florida in the summer months, usually due to cold air aloft.

5. Squall Lines. Not common in Florida, lines of thunderstorms are sometimes along a cold front and act like a squall line.

6. Warm and Cold Fronts. Frontal passages normally occur in the winter months. Frontal passages do not guarantee rain. During the summer months it is more common to have weak frontal zones that act as convergence zones and have few of the characteristic of winter fronts.

7. Tropical and Sub-tropical Cyclones. A significant portion of wet season rainfall is associated with tropical systems. The amount of rainfall is not necessarily related to strength or classical structure of the system. Hurricanes and tropical storms account for some wet season rainfall. Tropical cyclones consist of tropical waves, tropical depressions, tropical storms, and hurricanes.

8. Stationary Upper Level Low Pressure Systems. Truly stationary upper level low pressure systems are rare. Over Florida, these systems are usually found in June, September, or early October. Upper level low pressure systems combined with a front can produce heavy, sustained rain over a widespread area. Large rainfalls in the dry season are usually due to these systems.

c. Evapotranspiration (ET)

ET accounts for the major portion of rainfall loss and its evaluation is necessary in order to determine the amount of rainfall excess available for other purposes. Total losses from land areas depend on both losses from vegetation (transpiration) and losses from saturated ground and open-water areas (evaporation). Climatic influences on ET include radiation, temperature, humidity, and wind. The losses from evaporation pans and open-water areas are fairly uniform due to continuous supply of water. Losses from land areas may vary widely because of the greater variations in the amount of water available for ET. In a report entitled "Report of Runoff Investigations in Certain Florida East Coast Drainage Districts" determined that ET losses increase at a diminishing rate when rainfall exceeds the normal ET requirements. During dry periods, transpiration is limited by the moisture available in the root zone, and evaporation from the soil is limited to moisture brought to the surface by capillary action.

C&SF Project, Part IV, Supplement 2, Hydrology and Hydraulic Design, Section 1-DM, Storage Level in Lake Okeechobee At Beginning of Critical Hurricane dated October 13, 1953, Appendix A, page A-6 and A-7 has a discussion of evaporation based on records from 1912 to 1952. That discussion is not repeated in this manual. Data contained in Table 4.2 is actual published data from Class A type evaporation pans for areas around Lake Okeechobee. Data is based on the period of record from 1943 to 1993.

Table 4-2
Representative Climatological Station Annual Evaporation

Station (inches)	**Average Annual Evap***
Belle Glade	61.83
Clewiston FS	56.39
Moore Haven	73.39
Stuar	N/A
	63.87

* National Climatological Data Center, Summary of the Day, data on CDROM. Data is average for period of record at each gage based on years with no missing data.

d. Wind

The generally light-to-moderate winds characteristic of the project area have little effect on routine regulatory operations; however, tropical cyclones and locally severe extratropical storms may periodically induce potentially hazardous wind-tide (i.e., storm surge) and wave conditions on Lake Okeechobee.

An analysis of tropical storm surges was performed during preparation of the March 1993 Special Report entitled C&SF Project, Herbert Hoover Dike, Seepage and Stability Analysis. That study concluded that under severe conditions, storm surges along some areas of the shoreline could reach elevations as high as 15 feet above the pre-storm water surface elevation. At any particular shoreline location, the height of the storm surge is dependent on a number of parameters including fetch length, local shoreline configuration and bathymetry, and characteristics of the storm such as atmospheric pressure deficit, wind speed, radius to maximum winds, forward speed, and storm track; therefore, for any particular storm, the surge elevations at different locations around the lake will vary considerably. Table 4-3 provides estimates of maximum (200-year recurrence interval) storm surge heights at selected sites. To estimate the maximum total lakeside water surface elevation at a site, the storm surge height would be added to the lake stage which existed prior to storm inundation. For example, if the pre-storm lake stage was 17.5 ft., NGVD, then the maximum water surface elevation with a 0.5% exceedance frequency storm surge at Bacom Point would be 26.8 ft., NGVD.

Table 4-3
Maximum Estimated Lake Okeechobee Storm Surge Elevations

Location	0.5% Storm Surge (ft.)
Northwest Shore (C-40)	4.3
Okeechobee (S-193)	9.5
Northeast Shore (S-131)	5.3
Port Mayaca (S-308)	5.7
Canal Point (S-352)	10.4
Bacom Point (C-10)	9.3
Hillsboro Canal (S-354)	12.9
Lake Harbor (S-354)	11.8
Clewiston (S-310)	10.8
Moore Haven (S-77)	14.9

More detailed information related to Lake Okeechobee storm surges is available in the previously mentioned Special Report and in an unpublished report entitled Application of an Empirical Simulation Technique to Lake Okeechobee Storm Surges. Copies are available on request.

In addition to storm surge, intense winds can also cause severe wave conditions on Lake Okeechobee. Waves are typically limited by the relatively shallow depths and short fetches characteristic of the lake; however, under severe conditions, significant wave heights may range from 7 to 12 ft., NGVD, depending on location, initial lake stage, storm surge elevation, and wind speed. Corresponding significant wave periods are estimated to range from six to eight seconds. The extent of wave run-up on the face of a levee is influenced by the wave and water level conditions as well as the levee slope. Estimates of wave run-up under tropical storm conditions range from 2 to 3 ft., NGVD in some locations to over 16 ft. NGVD where steep levee slopes exist, e.g., at some culvert locations.

It is possible that combinations of the wind-induced phenomena discussed above (i.e. storm surge, wave height, and run-up) could result in wave overtopping of the levee crest in some locations; however, the time period during which overtopping and related flooding would occur would be brief. Studies have shown that overtopping would result from wave run-up and attack which accompanied some storm surge event. Lake Okeechobee storm surge hydrographs indicate that high storm surge elevations have relatively short durations, with peak surges lasting only one to four hours; therefore, the duration of overtopping events would be similar.

The historical record indicates that tropical cyclones have resulted in heavy loss of life as well as substantial property damages; however, it should be noted that many of those storms occurred prior to construction activities which brought the levee system to its present state. For example, during the devastating hurricanes of 1926 and 1928, the levees at Lake Okeechobee offered little protection against the estimated seven and 13 foot surges which resulted from those respective storms. Conditions would be much different under the present protection provided by the existing Herbert Hoover Dike system. A list of tropical storms and hurricanes which have influenced Lake Okeechobee since 1886 is provided in Table 4-4, which was compiled from the National Hurricane Center's tropical storm database.

Typical wind velocities at stations around Lake Okeechobee range from about five miles per hour (mph) in July to nine or ten mph in March and April. Wind velocities along the east shore are generally higher than corresponding velocities at other locations. Measured data indicates that five-minute maximum recorded velocities associated with tropical disturbances have reached 92 mph near Lake Okeechobee and 132 mph at the Atlantic coast due east of the lake.

Table 4-4
Summary of Tropical Cyclones Near Lake Okeechobee

Name	NHC Number	Date	Maximum Wind Speed* (kts)
Unnamed	127	08/11/01	40
Unnamed	141	09/11/03	65
Unnamed	194	10/17/10	65
Unnamed	271	07/27/26	90
Unnamed	276	09/18/26	110
Unnamed	289	08/08/28	85
Unnamed	292	09/16/28	115
Unnamed	324	07/31/33	65
Unnamed	331	09/03/33	110
Unnamed	357	11/04/35	65
Unnamed	449	09/16/45	110
Unnamed	461	09/17/47	120
Unnamed	465	10/12/47	65
Unnamed	473	09/18/48	85
Unnamed	477	08/27/49	100
King	499	10/18/50	75
Unnamed	521	08/29/53	35
Hazel	530	10/09/53	60
Donna	597	09/10/60	115
Cleo	629	08/27/64	85
Isbell	635	10/14/64	110
David	777	09/03/79	85
Keith	864	11/23/88	35

* Wind speed during the period when the storm was in vicinity of Lake Okeechobee.

4-06. <u>Storms and Floods</u>

The wet season in peninsular Florida normally begins in May or June and continues through October. During the summer months thunderstorms caused by differential heating are typical for this area. Such thunderstorms are generally small isolated cells directed by low-intensity pressure gradients. The area is also subject to excess summer rainfalls associated with tropical easterly waves that, at times, develop into tropical storms and hurricanes. The incidence of tropical storms of varying intensities is a critical factor in regulatory planning for C&SF Project facilities. The necessary regulation schedule must maintain levels in major lakes and reservoirs that would be safe even with the occurrence of hurricane wind tides and wave action, and at the same time have enough storage to control storm runoff and store enough water for dry-season irrigation requirements. This is accomplished by lowering stages in the early part of the year and storing water during September and October when runoff is usually heavy. Hurricanes which ultimately cross over or near South Florida usually affect project works in this area in three days or less from the time that storm warnings are ordered for the Florida coast, thus making it impossible to effect major adjustments in water levels in Lake Okeechobee. The ability to track tropical storms has become more technologically sophisticated; however, it is still impossible to anticipate the path, or effect, of a hurricane. Storm rainfall is equally difficult to anticipate; it can have little direct relation to the size or intensity of the storm. Although intense rainfalls amounting to four inches or more are common in Florida, serious flooding usually is the result of prolonged heavy seasonal rainfall aggravated by tropical storm or hurricane rains, and may affect large portions of the C&SF Project area.

Hurricanes are the most spectacular producers of heavy precipitation over the area. They are usually accompanied by very heavy rainfall near the eye of the storm, with moderate to heavy rains extending to a considerable distance, and with lighter precipitation over wide areas. The over-all contribution to water supply by hurricanes is far less than that of thunderstorms, because of their comparative infrequency and the limited area of extreme precipitation. There are great variations in intensity and areal distribution of hurricane rainfall. Some major hurricanes yield little more rainfall than other tropical storms of lesser force.

a. <u>1926 Hurricane</u>

On September 18, 1926 a hurricane entered Florida at Miami, passed about 50 miles south of Lake Okeechobee, and left the west coast of the State near Punta Rasa. More than 100 lives were lost, and heavy property losses occurred at Miami. About 400 persons were killed, chiefly by drowning, and heavy property damages were suffered in the vicinity of Moore Haven. Property damages in Miami and other Dade County communities alone were nearly $75,000,000. The Weather Bureau reported that the maximum sustained wind velocity was 128 miles an hour at Miami Beach, and that the lowest barometric pressure was 27.61 inches at Miami. The hurricane, at the time of its occurrence, was the most severe ever recorded in the United States.

b. <u>1928 Hurricane</u>

On September 16, 1928 a hurricane entered the State at West Palm Beach, passed across Lake Okeechobee somewhat north of the center of the lake, and proceeded northward from the lake to leave the State about 30 miles west of Jacksonville. About 2,700 lives were lost, chiefly from drowning around Lake Okeechobee, and heavy property losses were suffered in southern Florida. The Weather Bureau reported that the minimum barometer reading was 27.43 inched at West Palm Beach, which was the lowest on record at that time in the United States.

c. <u>1935 Hurricane</u>

The hurricane passed over Long Key and Lower Matecumbe Key, off the southern coast of Florida, and continued parallel to the west coast about 30 to 50 miles offshore. According to the Weather Bureau, the hurricane was probably the most intense of record, over a small area, to visit any portion of the United States. A corrected barometer reading of 26.35 inches was recorded at Craig, FL, which is the lowest pressure ever recorded in the Western Hemisphere, and one of the lowest in the world. The Weather Bureau also reported that winds of 150 to 200 miles an hour undoubtedly occurred with gusts probably exceeding 200 miles an hour. Four hundred persons were killed, mostly by drowning, on the Florida Keys.

d. <u>1944 Hurricane</u>

The hurricane entered the State on the west coast near Sarasota and continued north and northeastward to pass between Tampa and Plant City. It continued that course, passing east of Jacksonville, and left the State at Fernandina. Eighteen lives were lost as a result of the hurricane, and property damages in Florida were estimated at from $10,000,000 to $13,000,000. The greatest loss was to truck and citrus crops, which totaled about $50,000,000. The hurricane was accompanied by widespread, heavy rainfall.

e. <u>1945 Hurricane</u>

The hurricane entered the State at Key Largo, passed over Homestead, Winter Haven, Deland, St. Augustine, and Jacksonville Beach, and left the State at Fernandina. Four lives were lost, and property damages in Florida exceeded $54,000,000. The Weather Bureau reported that the maximum measured wind velocity was 138 miles per hour at Carysfort Reef Light, in the Florida Keys, and that the lowest barometer reading was 28.09 inches at Homestead Army Air Base.

f. <u>1947 Flood</u>

On September 17, 1947 a hurricane entered the State at Fort Lauderdale and moved westward, leaving the State north of Naples. Eleven lives were lost, and property and crop damages in the State amounted to about $59,000,000. Damages would have been much greater had not the center passed between the larger cities. The Weather Bureau reported the highest recorded wind was 155 miles an hour at Hillsboro Light, near Pompano, where the barometer fell to 27.97 inches. Since that station was not at any time within the eye of the storm, higher winds and lower pressures may have occurred at other points. Six to eight inches of rain fell over central and southern

Florida, which was already saturated by previous heavy rainfall. The resultant flooding produced the greatest damages of record over the entire southern part of Florida, and was particularly severe in the Lake Okeechobee-Everglades area. High water marks in the agricultural area adjacent to Lake Okeechobee were from one-half to four feet above surrounding terrain. In the Everglades areas, west of Fort Lauderdale and west and southwest of Miami, flooding to a depth of six feet and over was noted, with numerous reports of at least four feet. Flooding was quite general for 30 to 60 days. Extensive areas west of State Highway No. 7, along the West Palm Beach Canal, and along the lower reaches of North New River Canal, were still under water late in December 1947. In parts of those areas low-lying lands remained under water until early spring. Based on the 1947 flood, on minor floods which have a frequency of about once a year, and on a hypothetical flood of 100-year frequency, average annual flood losses were estimated as follows:

Kissimmee River basin and related areas ----------$1,500,000
Area affected by Lake Okeechobee-----------------$4,130,000

g. 1948 Flood

On September 21-22, 1948 a hurricane passed over Key West and entered the mainland near Everglades, passing over Lake Okeechobee between Clewiston and Belle Glade. It left the State near Stuart. Three deaths and damages of about $12,000,000 resulted in Florida from that hurricane. Rainfall amounting to 17.70 inches occurred at Clewiston during the period September 17-29. The average rainfall over the entire Lake Okeechobee Everglades area was about eight inches. The Weather Bureau reported that the lowest barometric pressure was 28.45 inches at Boca Chica, near Key West.

h. 1949 Hurricane

On August 26-27, 1949 a hurricane entered the State at Delray Beach, crossed the northern part of Lake Okeechobee, then proceeded northwestward to the west coast of Florida north of Tampa, where it turned northward through Florida into Georgia. There was little loss of life, but total damages in Florida were estimated at $45,000,000. The most severe hurricane to visit the Lake Okeechobee area since 1928, it produced the greatest wind damages ever experienced in Florida. Rainfall, however, was less than that accompanying previous hurricanes of similar intensity. The Weather Bureau reported that the lowest barometer reading was 28.17 inches at West Palm Beach, and that the highest wind velocity was 153 miles an hour at Jupiter lighthouse before failure of the instrument occurred.

i. 1950 Hurricane

On October 17-18, 1950 the hurricane entered the State at Miami, proceeded over Lake Okeechobee, and continued northward approximately parallel to the Florida east coast slightly west of Orlando. It passed into Georgia between Jacksonville and Lake City. As a direct result of the hurricane, four persons were killed, 16 received major injuries, and 183 received minor injuries. Property and crop damage in the State amounted to $27,750,000. The Weather Bureau reported the maximum recorded wind velocity at about 150 miles an hour at Miami. The lowest barometric reading was 28.25 inches at the same station. A barometer in the home of an employee of that office in the center of the storm read 28.20 inches. That instrument was carefully calibrated with the official barometer and was considered to be accurate.

j. 1957 Flood

Unseasonably heavy rains occurred over much of south-central Florida on December 23-25. Average rainfall over Lake Okeechobee exceeded all previous December records. Runoff and pumping into Lake Okeechobee caused the lake to rise from 14.65 ft. to 16.15 ft., NGVD during January 1958. Heavy runoff from the upland areas northeast of the lake caused flooding of about 20 square miles of low pasture lands along the lakefront. Estimated frequency of occurrence for this storm is about once in 10 years.

k. 1960 Flood

September 1960 was one of the wettest months within the history of the C&SFFCD. The major causes were rainfalls resulting from hurricane Donna and the effects of tropical storm Florence. This rainfall created maximum flooding throughout much of the area. Approximately 20 to 40 inches of rainfall occurred over the greater portion of central and southern Florida for the period 21 July to 30 September. Antecedent conditions of stage and discharge in the Kissimmee Basin were above normal. The month prior to the hurricane the State Highway 70 discharge was 3.9 times the normal. The monthly rainfall throughout the basin approximated eight inches above normal. This rainfall has a frequency of approximately once in 15 years. Passage of hurricane "Donna" over lakes in that region caused some flooding from wind tides. Wind tides were four to five feet on Lake Okeechobee and one foot or more on smaller lakes in Kissimmee River Basin. Maximum water surface elevation on the northwest shore of Lake Okeechobee approximated 20 ft., NGVD, 5.5 ft., NGVD above the 14.5 ft., NGVD lake stage. Damages to agriculture and urban land in this area were estimated at more than $14 million, and the agriculture damage alone was over $11 million.

l. 1969 Flood

Heavy rains occurred over much of south-central Florida in March 1969. Most intense rains occurred in the south shore of Lake Okeechobee. Belle Glade, Moore Haven and La Belle had rainfalls of 3.06, 3.41, and 4.38 inches above normal, respectively. Lake Okeechobee itself was 2.74 inches above normal. Between March 8 to 10 and March 16 to 17, two large inflows were brought into the lake and raised the peak stage of Lake Okeechobee to 15.73 ft, NGVD. At that time some large releases were made through St. Lucie canal, Caloosahatchee canal, and Agriculture canal. A continuous wet summer did not allow lake stage to draw down instead Lake Okeechobee maintained an average of 14.26 ft, NGVD throughout the summer. A tropical storm brought 9.1 inches of rainfall to Lake Okeechobee during October. The maximum stage at that time was 16.48 ft, NGVD. Even though large releases were made through the canals, the lake stage stayed above regulation schedule throughout the rest of the year. This was caused by an unseasonably wet November and December.

m. 1983 Flood

In January and February 1983, south Florida was drenched with heavy winter rainfall and required maximum regulatory releases through all major lake outlets. Over two million acre-feet of water were released to the sea through the St. Lucie Canal and the Caloosahatchee River during the winter and spring of 1983.

n. 1995 Extreme Rainfall Event

Heavy rains attributable to Hurricane Opal and a stalled front produced one of the wettest Octobers on record. Moisture associated with Tropical Storm Opal focused moderate to locally heavy rains over central and western sections of the SFWMD on the first and second. During the first half of the month, flood control pumping in the EAA was moderate. In the second half of the month, the heavy rainfall and rising canal levels prompted the SFWMD to increase pumping to maximum and terminate releases from Lake Okeechobee into the EAA. Backpumping into Lake Okeechobee at S-2 and S-3 was needed. Canal levels were very high in spite of that pumping. Lake Okeechobee rose from its flood regulation Zone C to Zone A during the second half of the month. The lake peaked at 18.64 ft., NGVD on the 26th and ended the month just below Zone A. The Corps increased regulatory releases from the lake from Zone C releases to Zone B releases and then to Zone A releases. The high lake stage caused more seepage than normal through its perimeter levee. The Corps monitored the condition closely and took necessary measures as needed.

4-07. Runoff Characteristics

Lake Okeechobee has a watershed of about 5,500 square miles, consisting of the lake surface, Kissimmee River basin, and several smaller tributary areas. The watershed covers most of the central part of the State south from Orlando to the Lake Okeechobee agricultural area and generally east of the low ridge which divides the waters which flow into the Atlantic from those which flow to the Gulf of Mexico. The individual drainage basins in the area constitute a single watershed, as in most cases their waters intermingle during periods of heavy rainfall and their problems of water control and use, as well as their economic problems, are closely interrelated. The principal streams contributing to Lake Okeechobee are shown on Plate 2-1. Pertinent features of each area are discussed briefly in the following paragraphs.

a. Kissimmee River Basin

The major tributary area is about 100 miles long and embraces an area of 3,260 square miles. It is drained by Kissimmee River (C-38), whose tributaries and lateral canals connect the many small lakes of the area with Lake Okeechobee.

b. Indian Prairie and Harney Pond Canals

Indian Prairie Canal, about 16 miles long, and Harney Pond Canal, about 15 miles long, drain the low ground bordering the northwesterly shores of Lake Okeechobee. Their drainage areas are not defined and together they constitute about 320 square miles of land adjacent to the lake. During the short period of record, discharges have ranged from zero to about 4,000 cfs for Indian Prairie Canal, and from zero to about 1,900 cfs for Harney Pond Canal.

c. Fisheating Creek Basin

Fisheating Creek, about 51 miles long, drains an area of about 560 square miles bordering the westerly shores of Lake Okeechobee. The discharge from the creek is uncontrolled, and has varied from zero to 29,600 cfs at the Palmdale gaging station. During the October 1951 flood, it was estimated that the Fisheating Creek discharged a peak rate of 35,000 cfs into Lake Okeechobee.

d. Northeast Shore Area

The tributary area bordering the northeasterly shore of Lake Okeechobee, comprising about 200 square miles, drains into the Lake by numerous small streams. The largest of those streams, Taylor Creek, drains the 109 square mile northerly portion. Its discharge has ranged between zero and 4,500 cfs.

4-08. Water Quality (Nutrients)

The following information was taken from previously unpublished Corps data from stations sampled quarterly over a 01 Jan 91 thru 18 Nov 95 time frame. Lake Okeechobee contains highly mineralized water dominated by calcium, sodium, chloride, and bicarbonate ions. The Lake also has moderately high and variable color levels (35-60 Pt-Co Units), high daytime dissolved oxygen (DO) concentrations (>6-8 mg/L), and an average oxygen (O_2) saturation of 100 percent. The major ions, conductivity, and color display no apparent seasonal variations. DO concentrations are usually lowest in the summer and highest in winter. Lake mean annual turbidity averages above 40 Nephelometric Turbidity Units (NTU) with values as high as 90 occurring, probably as a result of wind-driven wave resuspension of bottom settlement.

The water entering Lake Okeechobee from tributaries has diverse water quality characteristics. Water entering the south end of the Lake from S-2 and S-3 is typically very high in dissolved solids (means of 651 mg/L and 630 mg/L, respectively). This is in contrast to the water entering the north end of the lake via S-65E (mean of 170.2 mg/L) which is relatively low in dissolved solids. Turbidity and total suspended solids are very low while color is typically high at all the inflows. Mean daytime DO concentrations are mostly moderate (4-6 mg/L) at the inflow points to the Lake.

The highest average mean annual ortho- and total phosphorus (TP) concentrations have been measured in Kissimmee River at S-65/SR 60 (0.872 and 0.825 mg/L, respectively). These high levels of phosphorus may be caused by animal waste from dairy farms and beef cattle pasture. As a result of the high phosphorus concentration, Kissimmee River at S-65/SR 60 has exhibited a low total nitrogen (TN) to TP ratio (1.5) indicating a large excess of phosphorus relative to plant requirements. The Caloosahatchee River has the highest mean annual TN concentration of 2.06 mg/L. This is similar to North New River Canal below S-2 with a reading of 2.03 mg/L. A high nitrogen concentration may be a result of nitrification in the EAA Basin and mineralization of muck soils. Though many nutrients are required for algal growth, phosphorus and nitrogen are the most common limiting nutrients for net primary production, and thus the standing crop biomass of algae and nuisance aquatic weeds in the Lake.

The lowest TP concentrations are from stations within Lake Okeechobee at lake level stations LS-14, LS-12, and LS-16 (0.47, 0.17 and 0.17 mg/L, respectively). The Miami Canal at S-3 has the second lowest mean average annual TP concentration (0.276) of any station around the Lake excluding rainfall.

4-09. Channel and Floodway Characteristics

a. Caloosahatchee River

The first major flood-control outlet for the lake was a channel begun in 1884, connecting Lake Okeechobee with the headwaters of the Caloosahatchee River, to improve access to the lake. The original channel was improved a number of times between 1906 and 1935, the last improvement being made by the Federal Government. The existing navigation project on the Caloosahatchee River, providing an eight-foot channel 90 feet wide from Ft. Myers to Lake Okeechobee, was completed in 1949. Water elevations within the upper portion of that reach are controlled by Structure 78 near Ortona, and discharge from the lake is controlled by Structure 77 on the westerly shore of the lake. About 1,040 square miles of land drain directly into the Caloosahatchee River in the reach between the lake and Ft. Myers.

b. St. Lucie Canal

The canal was constructed when it become apparent to local residents that an additional outlet to Lake Okeechobee was necessary if flood hazard to low-lying lands around the lake was to be reduced. St. Lucie Canal was begun in 1916 and was practically completed by 1924, although it did not function effectively because of bars which formed in this new canal as a result of storms occurring during 1924 and 1926. The canal was first placed in fairly effective service in August 1926. Flow through the canal is controlled by Structure 308B on the eastern shore of the lake and Structure 80 at the lower end of the canal.

c. Agricultural Canals

As early as 1900, settlers started developing the rich muck lands immediately south of Lake Okeechobee. Because of the wet character of those lands, drainage was the primary requirement for successful development. Construction of four major canals to drain the area started when the Everglades Drainage District began large-scale work in 1906 and progressed as funds became available until about 1929. During the period from 1906 to 1910, 11.2 miles of North New River Canal and 4.2 miles of Miami Canal were excavated. By April 1913, Miami and North New River Canals were completed to partial dimensions to the ocean, and work on West Palm Beach Canal had been started. At that time, Hillsboro Canal was being constructed; although it had not been excavated to the ocean, it was discharging water from the lake to the Everglades. Those four canals were only partially successful in providing adequate drainage to the area suitable for development south of the lake, although they did permit partial development of the area. Discharge from the lake through those canals was largely limited to low flow periods before project improvements.

4-10. Economic Data

The Lake Okeechobee basin is located within nine south-central counties including St. Lucie, Highlands, Osceola, Martin, Polk, Okeechobee, Glades, Palm Beach, and Hendry counties. The project area is sparsely populated with primarily an agricultural economy.

a. Population

The State of Florida experienced a tremendous population growth after World War II. The number of people more than tripled between 1950 and 1980 (see Table 4-5) chiefly due to in-migration. Population forecasts predict approximately 14 million persons by the year 2000 with in-migration accounting for more than 90 percent of future growth. Population figures for counties and municipalities within the central project area are given in Table 4-6.

Table 4-5
Population in Florida

Year	Florida Population (in thousands)	Percent Change	Percent of U.S. Population
1950	2,770	----	1.8
1960	4,950	78.7	2.7
1970	6,790	37.2	3.3
1980	9,740	43.5	4.3
1990	12,900	32.4	5.0

Table 4-6
Populations in the Lake Okeechobee Region

County & Municipality	Population(1993)
Palm Beach County	918,200
Pahokee	6,856
Belle Glade	17,249
South Bay	4,064
Hendry County	28,100
Clewiston	6,144
Okeechobee County	31,800
Okeechobee	4,979
Glades County	8,300
Moore Haven	1,538

b. Agriculture

In general, the entire Lake Okeechobee watershed is dominated by some type of agricultural activity. Cattle and dairy pasturelands are the main land use activities north and northwest of the lake while cropland (sugarcane, vegetables, etc.) dominate the drainage basins south and east of the lake.

c. Industry

Few areas within the Lake Okeechobee area have industrial land use. The primary industrial activities include manufacturing, mining, cooling water for power generation, citrus processing, and sugar refineries.

V DATA COLLECTION AND COMMUNICATION NETWORKS

5-01. Hydrometeorological Stations

a. Facilities

There is a coordinated monitoring effort between the CESAJ and the SFWMD on all relevant hydrologic and meteorologic sites for the purpose of operating and maintaining the functionality of the C&SF Project. The United States Geological Survey (USGS) plays an important part in maintaining and providing data from the hydrologic and meteorologic sites.

1. Corps

ER-1110-2-249, Engineering and Design, Management of Water Control Data Systems, dated 31 August 1994, defines the Water Control Data System (WCDS) as a dedicated special-purpose system of all hardware and software which has been acquired and is being used for acquisition, transmission, processing, display, and dissemination of hydrologic, meteorologic, water quality, and project data for the purpose of supporting the water control mission of the Corps. Within the Jacksonville District, the Water Management and Meteorology Section is the WCDS functionary.

The WCDS mission maintains sufficient resources to perform concurrent real-time hydrometeorological data acquisition and analysis for authorized projects. To provide the data needed for proper analysis, the Jacksonville District supports approximately 40 Data Collection Platforms (DCPs) through the Cooperative Stream Gaging Program with the USGS. See Table 5-1. DCPs are microprocessor-based devices installed at remote gaging stations which measure real-time data including water surface elevations, stream stages, reservoir elevations, and cumulative precipitation. Data are transmitted from the DCP via a Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS) satellite to an earth downlink receiver. Currently, data are collected by Internet or dial-up phone modem accessing mini-computers at USGS Sub-District Offices in Miami and Orlando, Florida. Data are transferred to the Water Management and Meteorology Section OS/2 Local Area Network server, which utilizes the Hydrologic Engineering Center Data Storage System software (HECDSS or DSS) for database storage.

Table 5-1
Cooperative Streamgaging Program Gages

USGS Station #	Location
02276400	Lake Okeechobee
02256500	Fisheating Creek
02292000	Caloosahatchee Canal (S-77)
02292480	Caloosahatchee Canal (S-78)
02292900	Caloosahatchee Canal (S-79)
02277000	St. Lucie Canal @ Stuart (S-80)
02276870	Port Mayaca (S-308)
263180080205001	WCA1 Site1-7
263050080145001	WCA1 Site1-8T
263000080120001	WCA1 Site1-8C
262750080175001	WCA1 Site1-9
262100080190001	WCA1 S-10A
262200080210001	WCA1 S-10C
262300080220001	WCA1 S-10D
262400080250001	WCA2A Site2-15
262240080258001	WCA2A Site2-17
261710080190001	WCA2A Site 2-19
260810080222001	WCA2B Site 99
261150080270001	WCA2A S-11A
261200080275001	WCA2A S-11B
261300080280001	WCA2A S-11C
261023080443001	WCA3A Site 62
261117080315201	WCA3A Site 63
255828080401301	WCA3A Site 64
254848080432001	WCA3A Site 65
02289019	Tamiami Canal at S-12B
02289041	Tamiami Canal at S-12C
254543080405401	Tamiami Canal at S-12D
255447080350200	L67A Pilot Test
255420080340500	L67C Pilot Test
255215080291000	WCA3B Site 34
255300080370001	WCA3B Site 69
255250080335001	WCA3B Site 71
260037080303401	WCA3B Site 76
02289060	Tamiami Canal/Levee 30
254100080402400	L67X-West
254100080402200	L67X-East
252523080352500	Taylor Slough @ S-332

As part of the WCDS design, the CESAJ has installed a Domestic Satellite (DOMSAT) Receive System (DRS) in which GOES data is immediately received and available for processing without delays experienced on the previous system due to various network and computer problems beyond local control. The DOMSAT system is being used to receive all GOES platform data for use in real-time operation of the Corps' Water Control projects associated with the C&SF Project, Herbert Hoover Dike, and navigation locks and dams. This system is the primary source of GOES data with backup from USGS sites in Miami, Florida. Other benefits include data collection redundancy and the ability to support others within the District using GOES and future support of other Division Districts. In the event the DRS malfunctions, data can be retrieved using the backup procedures of accessing mini-computers at the USGS Sub-District Offices in Miami and Orlando, Florida, using Internet or dial-up phone modems.

2. USGS

There are numerous USGS surface water gaging stations in and around the Lake Okeechobee and EAA Basins which are accessed via GOES and stored in the HECDSS data base (Table 5-2). There are also numerous ground water stations within the basins that are owned and operated by the USGS which monitor water levels in the Florida aquifer. The data gathered in the Lake Okeechobee and EAA Basins by the USGS is published annually in the U.S. Geological Survey Water-Date Report FL-YR-2A, and are also available on the Water Data Storage and Retrieval System (ADAPS) for those who have access to the USGS computer system or on CDROM. The Jacksonville District participates with the USGS in the gathering of data through the Cooperative Stream Gaging Program.

Table 5-2
HECDSS Condensed Catalog of Record Pathnames in File USGS.DSS

FISHEATING CR	NR LAKEPORT	ELEV
-------	NR PALMDALE	ELEV
HARNEY POND CNL	NR LAKEPORT	ELEV
HENRY CREEK	AT HENRY CR LOCK	ELEV
HILLSBORO CANAL	AT S2	ELEV
LEVEE4 CANAL	BLW G88	ELEV
LEVEE8 CANAL	AT WPB CANAL	ELEV
-------	NR CANAL POINT	ELEV
MIAMI CANAL	AT S3	ELEV
NUBBIN SLOUGH	NR SHERMAN	ELEV
OKEECHOBEE	HGS2	ELEV-HEAD
-------	HGS6	ELEV-HEAD
-------	S127	ELEV-TAIL
-------	S131	ELEV-TAIL
-------	S2	ELEV-HEAD
-------	-------	ELEV-TAIL
-------	S3	ELEV-HEAD
-------	-------	ELEV-TAIL
-------	S308	ELEV-HEAD
-------	-------	ELEV-TAIL
-------	S352	ELEV-HEAD
-------	S77	ELEV-HEAD
-------	-------	ELEV-TAIL
-------	S78	ELEV-HEAD
-------	-------	ELEV-TAIL
-------	S79	ELEV-HEAD
-------	-------	-----
-------	-------	ELEV-TAIL
-------	-------	-----
ST LUCIE	BLW S308	ELEV
WCA1	S6	ELEV-HEAD
WCA2A	S7	ELEV-HEAD
WCA3A	S150	ELEV-TAIL
WCA3A	S8	ELEV-HEAD
WPB CANAL	BLW S5AE	ELEV
-------	BLW S5AW	ELEV

3. SFWMD

The SFWMD takes observations at the pump stations and water control structures around Lake Okeechobee and the EAAs (Table 5-3). These observations are currently provided to the CESAJ via facsimile, and include rainfall, evaporation, gate settings, and pumping rates. Current plans are underway to update data exchange between the SFWMD and the Corps further by eliminating the need for exchanging data via fax to a system using internet file transfer capabilities set on a timer.

Table 5-3
SFWMD Observation Locations

Pump Station 2 (S-351)
Pump Station 3 (S-354)
Pump Station 4
Pump Station 127
Pump Station 129
Pump Station 131
Pump Station 133
Pump Station 135
Structure 352

b. Data Acquisition, Storage, and Retrieval

The HECDSS stores data in a fashion convenient for inventory, retrieval, archiving and model use. The user may interact with the data base through utilities that allow entry, editing, and display of information; application programs that read from and write to the data base; and library routines that can be incorporated in any program to access data base information. The DSS provides a means for storing and maintaining data in a centralized location; providing input to and storing output from application programs; transferring data between application programs; and displaying the data in graphs or tables. The HECDSS system is being utilized to maintain both real time data acquisition and historical archiving of water control data by the Water Management and Meteorology Section.

1. Corps

Locktenders provide daily data to the SFOO in Clewiston, Florida. This data is input to the HECDSS data base and transferred to Jacksonville via internet file transfer capabilities. By mid FY-96, all DCPs at the five locks and two intermediate sites on the OWW will be automated and files will be transferred by phone modem and a timer process to the SFOO and via the internet to Jacksonville. This data is used to prepare the morning report, weekly report, water budgets, and monthly summary of operations. The Okeechobee instrumentation project will also facilitate the locktenders' ability to monitor the locks and intermediate points by allowing dial-up access to the DCPs.

2. USGS

Data gathered by the USGS for the Corps through the Cooperative Stream Gaging Program is reported in near real-time. The data is gathered by DCP's which transmit the data via GOES satellite. The satellite transmissions are received and stored by the USGS in Miami, Florida and made available to all users that have access to the USGS computers. The satellite transmissions are also received, decoded, and stored by the Water Management and Meteorology Section through a DOMSAT Receive Station computer system. This data is used to prepare daily operation reports, water budgets, and monthly summary of operations.

3. SFWMD

SFWMD provides the data gathered by their observers via facsimile and by internet file transfer in the morning and afternoon. Data provided by SFWMD is entered into the HECDSS data base. The data are also used to prepare the morning report, weekly report, water budgets, and monthly summary of operations.

c. Maintenance

Under the Cooperative Stream Gaging agreement, the USGS maintains the Corps gages. Problems with gages should be reported to the USGS in Miami, Florida. The Corps and the SFWMD also maintain their network of gages within the basin.

5-02. Water Quality Stations

The Water Management and Meteorology Section does not operate or contract for the operation of water quality stations on Lake Okeechobee or in the EAA at this time.

5-03. Sediment Stations

The Water Management and Meteorology Section does not operate or contract for the operation of sediment stations on Lake Okeechobee or in the EAA at this time.

5-04. Recording Hydrologic Data

Data reported by the stations that are a part of the Cooperative Stream Gaging program are received and checked on a daily basis. These data are collected by a DOMSAT receive station located in the Water Management and Meteorology Section at four-hour intervals. The backup procedure for retrieving data is via internet or dial-up phone modem accessing mini-computers at USGS Sub-District Offices in Miami and Orlando, Florida. Data are transferred to the Water Management and Meteorology Section OS/2 Local Area Network server for database storage. Data are also provided to the Jacksonville District by the SFWMD. All data are either parsed automatically or hand entered into the DSS data base. A daily report containing this data is produced for in-house use within the Jacksonville District and is at the Water Management and Meteorology Section internet website. The agency responsible for O&M of the stations is responsible for archiving and maintaining the official station records. The USGS data are published annually in the U.S. Geological Survey Water-Date Report FL-YR-2A, and are also available on the ADAPS for those who have access to the USGS computer system. The SFWMD furnishes the Jacksonville District a monthly report entitled Water Conditions Report-Meteorological Summary. The meteorological data collected by National Oceanic and Atmospheric Administration (NOAA) is published in Climatological Data for Florida, Hourly Precipitation for Florida, and Storm Data. Some near real-time meteorological data and forecasts can be obtained from the NOAA State

Forecast Office in Miami, or from the computer data base at the River Forecast Center in Atlanta, Georgia.

5-05. Communication Network

The Lake Okeechobee and EAA portion of the C&SF Project is managed jointly by the CESAJ and the SFWMD in West Palm Beach, FL.

a. Regulating Office with Project Office

The regulation schedules for Lake Okeechobee are developed by the Jacksonville District in consultation with the SFWMD. The communication between the CESAJ and the SFWMD is done either by phone or in writing. Normal day to day operations are currently handled by the SFWMD with communication with the Corps on an "as needed" basis. During emergencies, communications are more frequent. See Chapter IX, Water Control Management, within this manual for more information.

b. Between SFWMD and Others

In 1977, SFWMD's real-time water management data acquisition system became fully automated. The telemetry and communications network for the SFWMD, the Supervisory Control and Data Acquisition System (SCADA), is controlled from the SFWMD's Communications Center in West Palm Beach. It provides centralized collection of water management data from remote sites, and the means to process and display the data for use in the formulation of management decisions.

5-06. Project Reporting Instructions

Data will continue to be reported to the Jacksonville District in the same manner that has been developed previously. The data will be collected by the SFWMD and furnished to the Jacksonville District on a daily basis.

5-07. Warnings

A flood warning system is not incorporated into the project. However, the SFWMD employs a staff of full-time meteorologists to assist in the operation of water control structures. These meteorologists make weather forecasts for the purposes of water management in the C&SF Project.

VI HYDROLOGIC FORECASTS

6-01. General

Water levels in the Lake Okeechobee and EAA are monitored daily by the Corps and the SFWMD. The water levels are monitored using staff gages and DCP's placed at project structure sites. The daily weather forecasts provided by the SFWMD staff meteorologists and the National Weather Service (NWS) are used for predicting the possible near real-time effect of rain in the basin on the water levels in these areas. However, no real-time data is collected in the basin for the express purpose of flood forecasting.

a. Role of the Corps

In an agreement reached in 1957, the SFWMD operates the structures around the lake for water supply purposes. In the event of flooding, the Corps operates the structures around the lake. The Corps also operates and maintains the levels in the Caloosahatchee River and the St. Lucie Canal. All other canal levels are maintained and operated by the SFWMD. The CESJA prescribes regulations for these areas and provides technical assistance on an "as need" basis. The Corps also monitors the water stages in these areas with data provided by the SFWMD (Chapter V) to insure that the lakes and pools are being operated in accordance with the water control plan (WCP). The Corps is not involved in the prediction of water levels or flood forecasting in the Lake Okeechobee and EAA.

b. SFWMD

The SFWMD employs two full-time meteorologists in the Operations Division. The meteorologists make daily forecasts for use in project operations. These forecasts include predicted rainfall by drainage basin and a synopsis of steering currents.

c. Role of Other Agencies

As mentioned previously, the project is operated and maintained by the Corps and the SFWMD. It is the responsibility of the SFWMD to insure that the regulation schedules are being followed and to maintain proper water levels for flood water storage, navigation, enhancement of fish and wildlife, and to provide water supply for nearby agricultural users. In addition, responsibility for water quality is with the SFWMD and the FDEP. TheUSFWS and the FWC are responsible for monitoring wildlife in the basin.

6-02. Flood Condition Forecasts

Flood condition forecasts are not made for the Lake Okeechobee and EAA. Rather, regulation schedules for the lakes and water levels for the adjoining canals have been developed on the basis of statistical analysis of historical data. The flood storage provided by the project is designed to handle SPF conditions. Slow runoff from the relatively flat watersheds, high ET rates, and the ability of the soil to retain moisture, make flood forecasting nearly impossible and impractical. For these reasons, no real-time data is gathered in the basin for the purposes of flood forecasting.

6-03. Conservation Purpose Forecasts

Lake Okeechobee experiences normal dry and wet periods. During these periods no conservation forecasts are made. However, during extreme periods of drought, the SFWMD forecasts water levels in Lake Okeechobee for the purposes of conservation. The SFWMD uses this forecast in their "Supply-Side Management" formula to make water supply allocations from the lake. The Corps reports the lake level in the "Drought Report" when necessary. Also, the Corps, in consultation with the SFWMD, has devised regulation schedules for these areas, taking into consideration the needs for water supply, navigation, water quality, and enhancement of fish and wildlife.

6-04. Long Range Forecasts

Long range forecasts are made based on a statistical analysis of historical data gathered in the basin. These forecasts are incorporated into the regulation schedules for the lakes and pools. Regulation schedules are adjusted periodically based on new data and predictions of future water use in the basin. Adjustments to the regulation schedules may include periodic drawdowns for environmental reasons, holding the water stage in the lakes and pools higher than normal during unusual prolonged wet conditions, and making releases for water supply to agricultural users during drought conditions.

VIII EFFECT OF REGIONAL OPERATING MANUAL

8-01. General

Lake water levels are regulated by a complex system of pumps and locks collectively known as the C&SF Project. The system is jointly managed by the Corps and the SFWMD. The regulation schedule attempts to achieve the multiple-use purposes previously stated as well as provide seasonal lake level fluctuations. The present regulation schedule for the lake is designed to maintain a low lake stage of 15.65 ft., NGVD to provide both storage capacity and flood protection for surrounding areas during the wet season (summer and fall). During the winter, lake levels may be increased up to 16.75 ft., NGVD to store water for the upcoming dry season. The general plan of operation for Lake Okeechobee is based on the following: (1) protection of lands adjacent to the lake from flooding by lake waters and hurricane-driven wind tides; (2) maintenance of an eight-foot navigation channel across Lake Okeechobee, as part of the OWW; and (3) storage of water to meet the requirements of the agricultural area south and east of the lake.

8-02. Flood Control

Flood control works on Lake Okeechobee consist of a system of about 1,000 miles of encircling levees, designed to withstand a severe combination of flood stage and hurricane occurrence, plus the regulatory outlets of St. Lucie Canal and the Caloosahatchee River. The design discharge of Moore Haven Spillway is 9,300 cfs; that of St. Lucie spillway is about 16,000 cfs. Following removal of local runoff from the agricultural areas south of the lake, an additional regulatory capability of several thousand cfs is available through the Miami, North New River, Hillsboro, and West Palm Beach canals by pumping into the three WCAs. The crest elevation of the levee system surrounding the lake ranges from 32 to 45 ft., NGVD. The likelihood of overtopping the levees from having excess storage is almost non-existent. Possible flooding due to overtopping of levees within the Herbert Hoover Dike system is limited to short duration events involving wave run-up in addition to hurricane induced storm surge. The likelihood of such events is remote and the expected extent of flooding is minimal.

The C&SF Project provides regional flood protection for the agricultural and urban areas of south Florida. In the EAA and other agricultural areas, the criterion is to remove three-quarter inch of stormwater runoff per day. This is equivalent to a flood protection level of five to ten-year.

a. Pre-project

Elevations of the water surface of Lake Okeechobee have been recorded continuously since March 1912. The earliest records through September 1936 were collected by the Everglades Drainage District and since that date the Corps has been the collecting agency. The unusual fluctuations of Lake Okeechobee water surface in the earlier years of record was of little consequence because of lack of development around the lake. It was not possible to regulate the Lake until outlet canals were constructed. During the 1920's regulatory outlets were constructed by the Everglades Drainage District and extremely high stages were reduced. The St. Lucie Canal was first put into effective service in the fall of 1926. The Caloosahatchee Canal had been in existence prior to that time but its capacity was small and had exhibited little control over the lake elevations. The purpose of regulation of Lake Okeechobee was primarily to maintain the most desirable lake elevations in the interest of navigation, flood control, and agriculture. High lake levels existed from 1922 to 1927. This and the occurrence of the severe hurricanes of 1926 and 1928 with resultant losses intensified the demand by the public for lowering the lake level. During the construction period in the 1930's, the lake stages were purposely regulated to extremely low levels as a safety measure and as a means of facilitating construction. Prior to 1937 the outlet canals were operated with the general idea of having the lake level lowered from 17 ft. to 14 ft. Okeechobee datum, (15.56 ft.-12.56 ft. NGVD above mean sea level) by June of each year in order to protect against possible fall storms which would raise the lake level. The plan worked some years, but was not effective in other years because a systematic release plan was not followed. After the levee system was completed in 1937 the Corps began to assist the USGS in the collection of hydrological data. In 1940 a plan of operation was put into effect to maintain the lake elevation between 12.56 and 15.56 ft. NGVD above sea level at all times.

b. Basic Design Assumptions

Criteria for development of design runoff is intended to reflect resulting changes in runoff caused by changes in land use and drainage developments that may occur during the life of the project. In routings for the basic report it was assumed that the rainfall was distributed uniformly over the primary drainage area at the design frequency rate. Secondary rainfall was distributed uniformly over the adjacent contributing drainage area at a rate which when combined with the primary area would not exceed the depth-area-frequency relationship for the area as a whole. The capacity curves used were developed from the topographic map prepared for the Everglades Drainage District in 1935. Routing periods used for the SPF were taken as five-day and for the period of record 30-day. Three basic WCPs for Lake Okeechobee were studied in the basic report. The first plan provided for the minimum amount of construction required to protect lands adjacent to the lake from flooding. The second plan provided varying amounts of agricultural water as well as flood control. The third plan considered flood control, agricultural water storage, and reduced discharges through St. Lucie Canal. Basic design assumptions were later changed as new design information and computation methods became known, such as new topographic maps, additional stage and discharge data, and computerized methods of routings.

c. Basic Hydrologic Design Criteria

The C&SF Project was established to provide flood protection, drainage, water control, and municipal, industrial, and agricultural water supply for a large area of central and south Florida. The objective of the planning, design and post construction regulatory studies is to provide and operate the facilities necessary to obtain the broadest benefits in the project area at a reasonable cost. The studies and planning were necessary to obtain this objective. The alternative would have been continued haphazard development of the area under the disruptive influences of flood and drought with eventual loss of irreplaceable resources of water and soil.

1. Design Procedures

The SPF is defined as the most severe storm, or sequence of storms, considered characteristic of a particular region. In initial project formulation studies, rainfall values for design were taken from maximum depth-area-duration curves for areas and combination of area pertinent to the southern portion of the project. An enveloping depth-duration curve was plotted for each of the selected areas for durations of one day to 12 months. The Standard Project rainfalls for those areas were then taken from the depth-duration curves. In 1953, following completion of Part VI, Section 6 studies, the Standard Project Storm was derived by using the 100-year storm values from rainfall-frequency charts in that report and increasing the values by 25 percent. Monthly distribution of rainfall was arranged so that the maximum amounts would occur during the peak hurricane season. Daily rainfall in the peak month was arranged so that the maximum five-day rainfall occurred during the first five days of the month. The daily rainfall experienced during the 1953 wet season was used as a basis for prorating monthly values to a daily distribution.

In addition to large variations in areal distribution of rainfall over the project area, there are seasonal and year-to-year differences. Data for hydrologic studies in the project area were developed on the basis of the 50 drainage areas used in the Water Resources Report for Central and Southern Florida, and in Volume 1, Basic Information Report, Regulation Manual, C&SF Project. The studies showed that very rapid changes from unusually dry to unusually wet conditions and the reverse can occur over large areas. Relationship between rainfall amounts, frequency of occurrence, and duration were developed. Missing rainfall information in long-term station records were estimated by multiple regression equations.

2. Seepage Losses

In Part I, Supplement 39, the pump station and the borrow canal adjacent to Levee D-1 were designed to discharge lake seepage estimated at 70 cfs per mile of levee under design conditions, in addition to the area runoff. The seepage relationship was derived assuming the one-in-ten year lake elevation of 18.5 ft., NGVD and a water surface elevation of 13.0 feet in a continuous borrow canal. In preparation of the water budget for the monthly report of operations, seepage is not considered as a loss from Lake Okeechobee because it is only a minor amount for the normal range of operations.

3. Area-Capacity Relations

Area capacity curves were developed for all major lakes and storage areas in the C&SF Project. The reliability of design studies and the dependability of the regulation plans are dependent on the accuracy of the area-capacity curves which were developed from the contour maps of the area. Sometimes the storage area of a lake or reservoir is changed by the construction of project works. An example of this is Lake Okeechobee. The first area-capacity curves were developed based on Everglades Drainage District maps long before the completion of the entire levee and structure system. Routings for the present lake levees were based on 1956 curves. As new parts of the project are completed the storage volume and area at different elevations change. Such a revision was made in 1962 when the northwest shore facilities were completed. The curve in use at the present time for Lake Okeechobee was revised in November 1968 to reflect loss of storage above 15.5 ft NGVD due to the northeast shore levees.

d. Spillway Design Flood

Design flow criteria were developed from synthetic runoff relations presented in Part IV, Section 9. The criteria were considered applicable to the developed drainage system of major and secondary canals in the C&SF Project area. Synthetic unit hydrographs of six-hour unit duration were derived for segments of the drainage areas of several parts of the project.

e. Standard Project Flood

The SPF runoff was computed by application of direct runoff-excess values to the composite unit hydrographs for the land areas, and then adding the estimated base-flow rates. Ten-year peak discharge rates were determined by application of the rainfall-excess amounts to the peak period of the composite unit hydrographs. For the areas directly tributary to the secondary drainage works, the peak runoff was estimated by drainage area proportion. Procedures for determining rainfall excess area described in Part VI, Section 8, DM, Rainfall-Excess Evaluation. A removal rate of three-quarter inch per day was generally used for pump station design on large agricultural lands.

Additional sources of information on design flood analysis for Lake Okeechobee and the WCAs include the basic report, C&SF Project DPR Part I, Part IV, Supplement 2, Section 5, Part IV, Supplement 21, and the 1968 Water Resources Report**.**

8-03. Recreation

Lake Okeechobee offers a variety of recreational opportunities for both Florida residents and tourists and represents an important economic resource for the region. The lake is nationally renowned for excellent duck hunting, largemouth bass and black crappie fishing. In 1987, a national poll of professional bass fisherman rated the "Big O" as the top bass fishing lake in America. The city of Okeechobee chamber of commerce extols itself as the "Speckled Perch Capital of the World."

Although lake and canal levels aren't managed specifically for recreation, they do affect recreation resources. For example, boat launching ramps, pleasure-crafts, sightseeing vessels, bank, and small boat fishing are all influenced by lake levels.

8-04. <u>Water Quality</u>

Lake Okeechobee has fair water quality overall but the trend is worsening. The lake receives discharges from the Kissimmee River Basin, Indian Prairie Canal, Fisheating Creek, and the Taylor Creek Nubbin Slough Basin, as well as occasional inflow from the St. Lucie Canal Basin. The primary land uses adjacent to the lake are dairy farming and cattle ranching north of the lake and intensive sugar cane and vegetable farming south of the lake. Some citrus groves are present in the basin, urban land use is minimal.

Historically, the major sources of water quality problems are agricultural runoff from dairy and beef cattle ranch operations to the north; and backpumping of stormwater from sugar cane and vegetable farming operations to the south. The Kissimmee River also delivers nutrients to the lake from sewage that is discharged in the upper of the Kissimmee River Basin.

Water quality in the north end of the lake is characterized by high levels of phosphorus and coliform bacteria. Pesticide and nutrient levels are elevated in the south part of the lake. Lake Okeechobee receives varying amounts of nutrients, Biological Oxygen Demand (BOD), bacteria, and toxic materials, depending on location, season, rainfall, and drought conditions.

Historically, the primary goals of the SFWMD were to minimize flooding during periods of excess rainfall and to maximize regional water supply storage. The Water Resources Act of 1972 (Chapter 373 F.S.) clearly identified that the Water Management Districts had major responsibilities for the quality of both surface and ground water resources.

Water quality studies conducted by the USGS and the SFWMD in Lake Okeechobee during the 1970's indicated that the primary sources of phosphorous to the lake were inflows from the northern basins, while the primary source of nitrogen inflow to the lake originated from the EAA. The Southeast and South Florida District Water Quality Assessment, 1994 305(b), Technical Appendix Reports: "Phosphorous loading limits established for the lake by the legislature in Ch. 373, FS and effective July 1992 have still not been met. Results of recently completed research sponsored by the SFWMD indicate that because of internal recycling of lake phosphorous and the vast reservoir of phosphorous stored in the drainage basin in ground water and wetland and canal sediments, the lake water phosphorous concentration may not be lowered to acceptable levels for many decades or even a century."

8-05. <u>Fish and Wildlife</u>

Lake Okeechobee and the Everglades have long been noted for their excellent hunting and fishing. Research conducted by the FWC provided information on the vast fish and wildlife resources of the area. In addition to game birds the area serves as feeding and nesting grounds for many other species of birds.

Lake Okeechobee marshes provide significant resource for feeding and nesting activities of wading birds in south Florida. The extensive Lake Okeechobee littoral zone of emergent marsh is located primarily along the west shore of the lake from Clewiston to the Kissimmee River. These marshes form a band 0.8 to 14.5 km in width and occupy lake bottom elevations between 10.0 and 15.5 ft., NGVD. The landward extent of the marsh is limited by the Herbert Hoover dike which encircles the lake at about 15.5 ft., NGVD elevation contour. Hydrologic factors which can influence the utilization of the lake by wading bird populations include water depths within the marshes, recent rates of water level recession or rise, and conditions throughout the interior wetlands of south Florida during critical times of the year. The occurrence of wading birds within the marsh followed a distinct seasonal pattern, with the fewest birds occurring during the fall and winter months, followed by gradual increases in early spring, with maximum numbers occurring during May through July. Counts decline sharply during the late summer months (August and September). Water levels and rates of recession and/or reflooding of Lake Okeechobee marshes have a major effect on wading bird utilization. Successful feeding conditions require receding lake stages below 15.0 ft., NGVD to concentrate forage organisms. These stages provide sufficient marsh habitat with water shallow enough to enable wading birds to feed. A major prerequisite for successful wading bird nesting is that the ground beneath the colony during the nesting period be flooded (March through July), or that the colony be formed on an island to provide protection from predators. Of equal importance is the availability of favorable feeding conditions in Lake Okeechobee or nearby marshes.

The vegetation that now exists as the littoral zone of Lake Okeechobee has developed as a response to post drainage lake stages. Although complex, the relationship between the plant community and hydroperiod can be generalized into two influences: (1) the hydroperiod must meet the reproductive requirements of the community's indicator species with sufficient frequency to establish and maintain that species; and (2) the seasonal water level fluctuations must provide the conditions under which the indicator species is vigorous enough to exhibit the morphological characteristics required to characterize a distinct community type in the face of competition from other species.

Changes in the lake's water regulation schedule and littoral zone plant communities have allegedly had a negative impact on waterfowl and wading bird populations. The current regulation schedule frequently withholds up to 95,000 acres of potential feeding habitat from wading bird use. Higher lake stages physically restrict foraging efficiency of these birds. Aquatic herbicides have not been applied near (Everglades) snail kites nesting areas and this practice should be continued in the future. Another endangered bird species which utilizes the lake is the bald eagle.

The fishery of Lake Okeechobee represents a valuable recreational, commercial and economic resource for the region. Forty-three species of fish inhabit the lake. Of these, seven are typically considered saltwater species, but are able to survive in Lake Okeechobee because of high mineral (calcium carbonate) content of the water. Principle game fish sought by fishermen include black crappie, largemouth bass, bluegill, and redear sunfish. The commercial fishery includes bluegill, redear sunfish, catfish and bullheads, gizzard shad, striped mullet, and gar.

With abundant water and diverse aquatic habitats, Lake Okeechobee supports a wide diversity and abundant populations of amphibians and reptiles. Approximately 22 amphibians and 40 reptile species temporarily or permanently inhabit the lake or the surrounding levee. Amphibians and reptiles commonly utilizing the lake include alligators, frogs, tree frogs, sirens, softshell turtles, hardshell turtles, cottonmouth snakes, and water snakes. The majority of these species utilize the lake's extensive littoral zone.

Lake Okeechobee supports a variety of resident and migratory bird species. In south Florida, 379 bird species have been sighted and many of these birds utilize Lake Okeechobee at various times. Most notable resident birds include wading birds, double-breasted cormorants, anhinga, gallinules and coots, white ibis, limpkin, and the Everglades snail kite. Dominant waterfowl species include ring-necked duck, American pigeon, fulvous whistling duck, blue-winged teal, and mottled Florida duck. The Everglades snail kite, bald eagle, and woodstork are endangered species that inhabit the Lake Okeechobee area.

Approximately 24 species of mammals temporarily or permanently utilize Lake Okeechobee and the surrounding levees. Most notable are raccoon, round-tailed muskrat, armadillo, rabbits, mice, and the cotton rat. The mammals inhabiting the lake serve as primary or secondary consumers and some serve as prey items for predatory birds and reptiles.

8-06. <u>Water Supply</u>

During years of normal rainfall, the 15.65 to 16.75 ft., NGVD regulation schedule allows for an ample supply of water to be stored in Lake Okeechobee during wet periods for use during the dry season. The fact that a similar regulation schedule was in effect during the 1980-1982 drought helped avoid large economic losses to agriculture during that period. However, south Florida's rapid growth produces ever increasing water demands on the system each year.

During dry periods, increased water use and large dry season water losses to ET require an operational water allocation plan for Lake Okeechobee, especially when regional water supplies become low and may not meet anticipated service area demands. The SFWMD has developed a water supply management plan that requires various actions to be taken according to the severity of the conditions exhibited in the lake regulation schedule. The basis of this plan is an allocation scheme which parcels out lake water based on estimated water use for the remainder of the dry season. A target water level in Lake Okeechobee is established for the beginning of the wet season (June 1) and allotments are computed such that lake water levels will not fall below the critical target stage, assuming average climatic conditions. Operational flexibility is built into the plan in order to make available the special actions that proved successful during the 1981-82 drought.

A primary use of Lake Okeechobee is to provide water supply for adjacent urban and agricultural lands and a backup water supply for the lower east and west coast (Lee County) Florida counties. Currently, C-43 provides an important source of potable water for Lee County and the city of Ft. Myers and is also used as a source of water for irrigation by agriculture.

8-07. Navigation

A navigable waterway with a depth of eight feet exists from the Intracoastal Waterway at St. Lucie Inlet on the Atlantic Coast across the State by way of St. Lucie Canal, Lake Okeechobee, and Caloosahatchee River to the Gulf of Mexico. The St. Lucie Canal (C-44) forms the eastern navigational channel for the OWW. The Caloosahatchee River (C-43) is the western end of the OWW. Also included are control works in St. Lucie Canal and Caloosahatchee River for regulating levels of Lake Okeechobee. To maintain an eight foot project depth the lake stage should be maintained at 12.5 ft., NGVD. The navigation channel from the city of Moore Haven through Lake Okeechobee to the St. Lucie Lock has an authorized project depth of eight feet. This project depth is based on a Lake Okeechobee stage of 12.56 ft., NGVD. When the lake stage is below 12.56 ft., NGVD, the authorized project depth is not maintained.

8-08. Frequencies

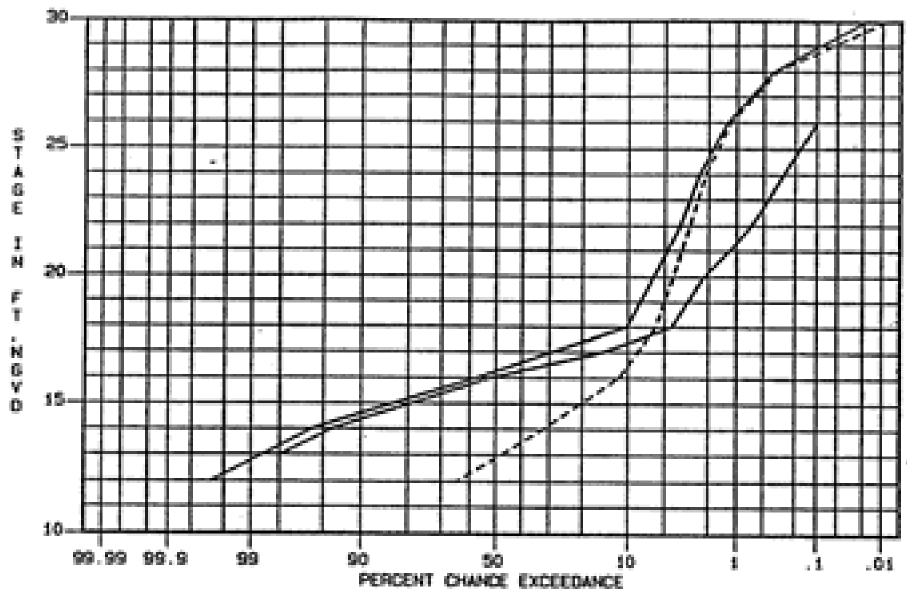
a. Peak Inflow Probability

With the interim lake range (15.5 ft. to 17.5 ft. NGVD) in effect flood routings performed in Part IV, Supplement 2, Section 7 resulted in a 30-day peak average lake stage of 24.5 ft. and 21.6 ft. NGVD for the SPF and the 100-year flood, respectively. Routings were performed with the following assumptions:

1. Agricultural canals have the first priority when regulatory releases are being made.
2. Agricultural canals provide for the removal of excess runoff from the agricultural area at the rate of three-quarter-inch a day. Capacity of the agricultural canals for lake regulation is about 5,600 cfs after local runoff has been removed.
3. Capacity of the Caloosahatchee River for lake regulation is reduced or eliminated during periods of local inflow. Releases are limited to a maximum of 9,300 cfs.
4. The St. Lucie Canal existing capacity of 14,800 cfs.
5. No discharge through Port Mayaca Spillway for five-day period of peak SPF local inflow to St. Lucie Canal.

See Appendix F for current flood routings performed for Run 25. The stage-frequency relationship for Lake Okeechobee presented in this Appendix considers the stage duration data obtained from Run 25, the rainfall data available for the period 1931-1993, and modified project conditions for the Kissimmee River.

A typical Lake Okeechobee stage-frequency relationship is depicted on the following page. This figure represents the exceedance frequencies associated with various water levels, consisting of both flood stage and storm surge components, at S-351. For example, the figure suggests that in any year, there is a one percent chance that the water surface elevation at S-351, considering both stage and surge, will be greater than or equal to 26.4 ft., NGVD. Similar relationships for other Lake Okeechobee shore sites are available on request.



S-351 Stage Frequency Relationships.

b. <u>Hurricane Wind Tides and Wave Action</u>

Project works around Lake Okeechobee are based on wind-tide determinations for hydraulic combination A, presented in Part IV, Supplement 2, Section 7. In the vicinity of Port Mayaca the critical windtide elevation with the interim and ultimate lake range in effect is 28.0 ft., and 31.0 ft. NGVD, respectively. Adding the wave run-up to the associated windtide, the required protection grade for each lake range is 37.0 and 40.0 ft. NGVD, respectively.

c. <u>Pool Elevation Duration and Frequency</u>

A 1950 memorandum from the Office of the Chief of Engineers reported on rainfall-frequency studies for the C&SF Project which included point rainfall frequencies for 2, 5, 10, 25, 50, and 100 years and for durations of 1, 2, 4, 6, and 12 months. Part VI, Section 6, DM, Rainfall Frequency Estimates was completed to supplement the data provided by the 1950 study. It described a general rainfall-frequency study which was used to obtain estimates of the probability of future occurrences of rainfall of various amounts and durations for periods up to 50 years. Most of the frequency curves were based on short records, therefore, the reliability of the data decreases as the rainfall frequency is extrapolated beyond 50 years. A stage duration analysis of Lake Okeechobee was performed recently for the time periods before and after the implementation of RUN 25. The results are shown on Figures 8-1 through 8-16, following the text.

IX WATER MANAGEMENT

9-01. Responsibilities and Organization

a. Corps

33 CFR 208.10 (Appendix D) requires that all structures and facilities constructed by the United States for local flood protection be continuously maintained and operated to obtain the maximum benefit of the project by an appropriate local entity. Some of the project works located within the Lake Okeechobee project area are owned by the Corps. The SFWMD owns many of the pump stations surrounding the Lake, including S-2, S-3, S-4, S-127, S-129, S-131, S-133, and S-135. They also own S-191 and several of the small boat locks, including Henry Creek Lock. Most of the structures are operated and maintained by the SFWMD. For those structures, the Corps serves in an advisory capacity regarding inspection, operation, regulation, maintenance, improvements or alterations. The role of the Corps is to provide and insure that the SFWMD follows regulations and that the project is operated to meet the prescribed project purposes.

b. Other Federal Agencies

No other Federal agency is directly involved in the management of the Lake Okeechobee project area. However, several Federal agencies are indirectly involved with the project or adjacent areas. These agencies include the NPS, the Department of Housing and Urban Development (HUD), USFWS, EPA, and the USGS.

c. South Florida Water Management District

The project works located within the Lake Okeechobee project area maintained and operated by SFWMD are in accordance with 33 CFR 208.10 and approved U.S. Corps System Operation Manuals.

d. State and County Agencies

State and local agencies indirectly involved in the project include the FDEP, FWC, Florida Department of Agriculture and Consumer Services, as well as numerous local governments.

9-02. Interagency Coordination

a. South Florida Water Management District

As an operator within the project, SFWMD has responsibility for coordinating with Federal, State, and local governments. SFWMD also makes press releases concerning various issues within the district including water quality, water usage, and water restrictions.

b. National Weather Service

The NWS provides long range forecasts for the basin for weather and precipitation. The meteorological data collected is published in bulletins such as "Monthly Seasonal Weather Outlook."

c. <u>U.S. Geological Survey</u>

Data collected by the USGS (U.S. Department of the Interior) is published annually in the "Water Resources Data-Florida" and is also available via the USGS mini-computer ADAPS system. Gages with GOES DCP's can be accessed via a DOMSAT receive station.

d. <u>National Park Service</u>

NPS (U.S. Department of the Interior) administers ENP.

e. <u>Other Federal, State and Local Agencies</u>

Contact is maintained with many agencies to insure that the project is meeting the intended objectives. These agencies include USFWS (U.S. Department of the Interior), USGS, EPA, FDEP, and the FWC.

9-03. Interagency Agreements

Interagency agreements are included in Appendix C of this manual.

9-04. Reports

Several different reports are produced to monitor the meteorologic and hydrologic conditions in the Lake Okeechobee area. These reports are produced by the Corps, SFWMD, and the USGS. The reports are shown in Table 9-1. Reports produced by the Corps are in accordance with ER 1110-2-240.

Table 9-1
Hydrometeorological Reports

Title	Agency	Contents
Morning Report	COE	Daily Water Stages
Drought Update (if req'd) Information	COE	Weekly Drought
Weather Forecast	NWS	Daily Weather Forecast
Drought Report	NWS	Palmer Drought Index
Monthly & Seasonal Outlook Forecast	NOAA	Long Range Weather
Water Resources Data-FL	USGS	Hydrologic Data
Meteorological Summary Data	SFWMD	Hydrologic & Meteorologic
Data/Computation Sheets	SFWMD	Hydrologic Data

Tables

Figures

PLATES

APPENDIX A

STRUCTURE DESCRIPTIONS AND RATING CURVES

APPENDIX B

PROJECT OPERATING MANUALS

APPENDIX C

DROUGHT CONTINGENCY PLAN

APPENDIX D
INTERAGENCY COORDINATION

APPENDIX E

FLOOD CONTROL REGULATIONS

APPENDIX F

STANDING INSTRUCTIONS TO PROJECT OPERATOR

APPENDIX G
MANATEE PROTECTION PLAN