CENTRAL AND SOUTHERN FLORIDA PROJECT

WATER CONTROL PLAN
FOR
LAKE OKEECHOBEE
AND
EVERGLADES AGRICULTURAL AREA

JACKSONVILLE DISTRICT
U.S. ARMY CORPS OF ENGINEERS
MARCH 2008

US Army Corps
of Engineers®

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NOTICE TO USERS OF THIS MANUAL

With only minor editorial changes this plan will become a chapter in the Master Water Control Manual for Lake Okeechobee and Everglades Agricultural Area. It is being published separately to consolidate the overall elements of the water control plan until the complete water control manual can be completed. This document will be superseded as a separate document when the complete manual is approved. Except for structure rating curves, this document supersedes all previous water control regulations contained in operations and maintenance manuals and similar documents pertaining to water control plans.

LAKE OKEECHOBEE OPERATIONS WEBSITES

U.S. Army Corps of Engineers Website:
www.saj.usace.army.mil/h2o/

VII - WATER CONTROL PLAN

7-01. General Objectives. Water management operations are determined through a decision-making process that considers all the Congressionally-authorized project purposes for Lake Okeechobee, the Okeechobee Waterway (OWW) and the Everglades Agricultural Area (EAA). These authorized project purposes include flood control; navigation; water supply for agricultural irrigation, municipalities and industry, the Everglades National Park (ENP), regional groundwater control, and salinity control; enhancement of fish and wildlife; and recreation. All elevations are in feet, National Geodetic Vertical Datum of 1929 (ft., NGVD) unless otherwise noted. A footnote has been included at the bottom of each page for ease of reference.

7-02. Constraints. This section is grouped into general subsections for ease of reference. Note that constraints are defined as structural, meteorologic, environmental, and hydrologic conditions that restrict, prevent and/or result in water management operations contained in this document. These constraints may become interrelated and typically evolve under specific circumstances such as, but not limited to, physical, legal, political, social and major conflicts between authorized project purposes (i.e. flood control, water supply, environment, navigation and recreation). All applicable constraints are considered in the decision-making process for determining water management operations. For information on the specific water management operations, refer to sections 7-03 through 7-12.

a. Structural Constraints.

1. Herbert Hoover Dike (HHD) Integrity Issues. Records covering the performance of the HHD system during major flood events indicate that the embankment and foundation of the structure are susceptible to significant seepage and piping erosion (seepage containing material) when the lake reaches critical levels. There is limited potential for HHD failure with lake elevations lower than 18.5, but, as the lake level rises, so does the risk of HHD failure. Analytical studies show an HHD failure would be likely at one or more locations if the water elevation in Lake Okeechobee reached 21.0. The HHD Surveillance Plan dated June 2006 contains guidelines to perform regular inspections on the dike and prioritizes areas of concern intervals. In general, the Lake Okeechobee water level determines the inspection interval.

2. Florida Power and Light Company (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. The South Florida Water Management District (SFWMD), with U.S. Army Corps of Engineers (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 accidental drawdown of the borrow canal, or deliberate drawdown in the case of vandalism that occurred only hours before the FP&L dike failure in 1979.

3. Discharge Capacity at S-77 Spillway. The design capacity for S-77 spillway is 9,300 cubic feet per second (cfs) for all floods up to the Standard Project Flood (SPF) because the S-77 stilling basin was not designed to dissipate the energy for the higher lake stages. As a result, the maximum discharge at a lake elevation of 16.5 is approximately 8,900 cfs. This constraint limits releases from Lake Okeechobee by restricting S-77 spillway operations and may become a significant concern during high lake levels.

4. Discharge Capacity at S-78 Spillway and Ortona Lock. The design capacity for S-78 spillway is 8,660 cfs for all floods up to the SPF. However, during rainfall events over the Caloosahatchee River Basin (rainfall runoff) in conjunction with Lake Okeechobee releases via S-77, it has been determined that the actual maximum discharge rate at S-78 is approximately 9,300 cfs (combined discharge via S-78 spillway/Ortona lock chamber). For this reason, while considering rainfall runoff, the Lake Okeechobee release at S-77 is constrained to prevent no more than 9,300 cfs at S-78. This constraint limits releases from Lake Okeechobee by restricting S-77 operations and becomes a significant concern during high lake levels.

5. Structural Stability at Low Lake Stages. Concerns with maintaining acceptable structural factors of safety against overturning/sliding at structures S-71, S-72, S-84, S-65E, and S-191 may arise during a combination of low water levels in Lake Okeechobee and high water levels upstream of the structure(s). As of February 2008, the SFWMD is developing a structural solution to address this concern while maintaining the existing water management operational criteria.

6. Water Supply at Lake Stages Below 10.2. The ability to provide water supply releases at S-351, S-352, and S-354 to the EAA via gravity is significantly reduced as Lake Okeechobee recedes below elevation 10.2. Historically, the SFWMD

has installed temporary pumps to address this concern. The SFWMD is considering the installation of permanent pumps at these structures as a long-term solution to deliver allocated supplies to the EAA.

7. Water Supply at Lake Stages Below 10.0. The SFWMD's ability to provide water supply to the Brighton Reservation (Seminole Indian Tribe) from Lake Okeechobee via SFWMD's pump stations G-207 and G-208 is not achievable as Lake Okeechobee recedes below elevation 10.0. As of February 2008, the SFWMD is planning the installation of additional pumps in conjunction with the structural solution for the stability concerns mentioned above, providing a long-term solution to deliver water supplies to the Brighton Reservation.

b. Meteorologic Constraints.

1. Potential Spillway Gate Debris. There are temporary and permanent structures/facilities inside the Lake, including the Belle Glade Marina, the campground on Kreamer Island, and the Okee Taintee Recreation Area by the Kissimmee River. These areas could conceivably be flooded by either high lake levels or storm surge events creating significant waterborne debris. This debris can potentially block spillway gates at nearby structures, impeding necessary water management operations. For example, as a result of Hurricane Wilma in 2005, a mobile home was submerged upstream of a spillway gate, impeding normal operations for several weeks.

2. Storm Surge During High Tide at S-79. At S-79, the elevation of the gates in the closed position is 4.2. During storm surges at high tide, the gates are sometimes overtopped by the tidal surge. The lock operators will monitor the situation and close the gates in the event that the head is reversed at the structure. When the storm surge/high tide recedes, they will re-open the gates to maintain the headwater within its optimum range. This constraint may limit releases from Lake Okeechobee by restricting S-77 and/or S-78 operations.

3. Extreme Weather. Extreme weather events may cause detrimental impacts on lake water quality including clarity, suspended solids, etc. For example, during the 2004 and 2005 hurricane seasons, high winds in combination with long-term high lake levels caused wind wave action that resulted in long-term high turbidity levels. Eventually, the long-term high lake levels and long-term high turbidity levels negatively affected the lake ecosystem. Likewise, long-term lake releases at S-77 and S-308 containing high turbidity levels negatively affected the downstream estuary ecosystem.

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This constraint may limit releases from Lake Okeechobee by restricting S-77/S-308 operations and may become a significant concern during high lake levels and long-term releases.

4. South Fork of the St. Lucie River. The St. Lucie Settlement subdivision on the South Fork of the St. Lucie River experiences flooding during high rain events. The flooding can occur when rainfall in the subdivision, wind in the St. Lucie estuary/South Fork of the St. Lucie River, tidal surge, and/or S-80 discharges occur. Due to the potential for flooding, the S-80 tailwater should not exceed elevation 3.0 when the discharges are being conducted. This includes reducing ongoing discharges at S-80 and S-308 when storm-induced and/or daily tidal surge is expected to cause a S-80 tailwater elevation of 3.0 or above. This constraint limits releases from Lake Okeechobee by restricting S-308 operations and becomes a significant concern during high lake levels.

c. Environmental Constraints.

Water Quality in Lake Okeechobee. Water quality measurements were first documented in 1970. The current five-year average load is more than four times higher than the Total Maximum Daily Load (TMDL) of 140 mt/yr (five-year average) considered necessary to achieve the state of Florida's in-lake Total Phosphorus (TP) target of 40 parts per billion (ppb). Despite a long history of regulatory and voluntary incentive-based programs to control phosphorus inputs into Lake Okeechobee, no substantial reduction in loading occurred during the 1990s. As a result, the Florida legislature passed The Lake Okeechobee Protection Act (LOPA) [Section 373.4595, Florida Statutes, (F.S.)] in 2000, mandating that the TMDL be met by 2015 and that the SFWMD, Florida Department of Environmental Protection (FDEP), and FDACS work together to implement an aggressive program to address the issues of excessive TP loading and exotic species expansion. In 2007, the Florida legislature substantially expanded the LOPA to include protection and restoration of the Lake Okeechobee watershed and the Caloosahatchee and St. Lucie Estuaries. The revised legislation requires the SFWMD, in collaboration with coordinating agencies, to develop a Technical Plan for Phase II of the Lake Okeechobee Watershed Construction Project (LOWCP) by February 1, 2008, and River Watershed Protection Plans for the Caloosahatchee and St. Lucie River watersheds by January 1, 2009.

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. The Interim Action Plan (IAP) was implemented by SFWMD in 1979, and formalized in the Lake Okeechobee Operating Permit (LOOP), as a

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means to reduce the nitrogen loading to Lake Okeechobee from the EAA by diverting EAA water to the Water Conservation Areas (WCAs) during flood control activities. Waters are only discharged from EAA canals into Lake Okeechobee when the EAA runoff exceeds the capacity of the pump stations S-6, G-370, and G-372 to transfer EAA canal water to the WCAs via Stormwater Treatment Area (STA) 2 and STA-3/4. To recognize flood protection objectives while minimizing environmental damage to both Lake Okeechobee and the WCAs, pumping at S-2 and S-3 is restricted to the minimum required for emergency flood protection in the EAA.

d. Hydrologic Constraints.

1. S-77 Tailwater Restrictions. Through past experience during rainfall events over the Caloosahatchee River Basin, in conjunction with Lake Okeechobee releases, it has been determined that a S-77 tailwater above elevation 12.0 has the potential to impact local drainage in and around the town of Moore Haven. For this reason, the S-77 tailwater stage as a result of Lake Okeechobee releases typically is not allowed to exceed elevation 12.0. This constraint limits releases from Lake Okeechobee by restricting S-77 operations and becomes a significant concern during high lake levels.

2. High-water Limitation at S-80. Normally, during heavy rain events and at high tide, an effort is made to keep the S-80 headwater within elevations 13.5 and 15.5. During high-water events, at around elevation 17.3, the machinery pits at the structure are in danger of becoming flooded. Monitoring by the lockmaster for this situation at the S-80 headwater should begin at approximately elevation 16.5. This constraint limits releases from Lake Okeechobee by restricting S-308 operations and becomes a significant concern during high lake levels.

3. Minimum Canal Levels - St. Lucie Canal. Canal water levels are highest and land elevations are lowest at the Tieback Levee of C-44 near Lake Okeechobee. 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 (C-44) using similar dredging techniques. Lake Okeechobee discharges and boat wakes have been frequent enough to prevent natural bank stabilization and have induced bank erosion. To limit the extent of bank erosion caused by sloughing during decreasing discharges from Lake Okeechobee, adjustments to water management operations may be performed as necessary and may result in the need to reduce and/or delay S-308 releases.

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In addition, to help reduce erosion upstream of the dam due to high velocities, the minimum headwater elevation at St. Lucie Spillway (S-80) during Lake Okeechobee releases, shall be no lower than 10.0, whenever possible.

However, during Lake Okeechobee releases, an effort should be made to prevent the headwater at S-80 from receding below elevation 12.0, whenever possible, in order to avert cavitation problems with the nearby local irrigation pump intakes.

4. Gap at Florida East Coast Railroad (FECRR) in St. Lucie Canal Tieback Levee. Gaps were left in the tieback levees where the FECRR crosses the St. Lucie Canal approximately one mile east of Port Mayaca. The low point of the gaps is at approximately elevation 24.5. 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 FECRR will be notified by the Corps' South Florida Operations Office (SFOO) 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). Flood levels may also require the sandbagging of gaps in the tieback levees.

5. Algal Blooms – St. Lucie Canal, Caloosahatchee River and Associated Estuaries. During dry and/or high temperature periods, there is a potential for the Caloosahatchee River (C-43) and St. Lucie Canal (C-44) to have an algal bloom develop. Short-term high rates of release from Lake Okeechobee are often effective at breaking up such algal blooms.

6. St. Lucie and Caloosahatchee Estuaries. High volume discharges may impact oyster spawning, the salinity envelope, water quality and overall ecological health in the St. Lucie and Caloosahatchee Estuaries. This constraint may limit releases from Lake Okeechobee by restricting S-77/S-308 operations and may become a significant concern during high lake levels.

7. STA Capacity Limitations. Extreme weather events may cause damage to the STAs and impair their ability to treat water for extended periods of time (e.g., 2004-05 hurricane seasons). Lake Okeechobee releases to the WCAs can be limited if STA treatment capacity is not available. This may become a significant concern during high lake levels.

8. Salinity Intrusion - Caloosahatchee River. During dry periods, Caloosahatchee River flow at S-79 may decrease such that navigation lockages through the W.P. Franklin Lock allow a

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saltwater wedge to move upstream of S-79. Normally, lockages are conducted “on demand”, which provides numerous opportunities for the saltwater wedge to move upstream. Eventually, the chloride content of the water available for the municipal water intakes at the Olga Water Treatment Plant may exceed the State’s drinking water standard of 250 parts per million (ppm).

When the chloride level above S-79 is rising and reaches 180 ppm, the SFWMD can request that the Corps reduce the number of lockages occurring at S-79 to one lockage every four hours (for additional details, see the Drought Contingency Plan referenced in Appendix B of the Master Water Control Manual). When the number of lockages are reduced at S-79, the number of opportunities for saltwater wedge migration to occur are reduced.

In addition, the SFWMD typically requests the Corps to implement a short-term high rate of discharge from Lake Okeechobee to flush the high chloride content water through S-79.

9. Indiantown Marina at S-80. When the St. Lucie Canal at S-80 headwater recedes to around elevation 13.5, the Indiantown Marina begins to experience mooring problems (i.e. problems with reaching the dock safely and securing the lines) with large vessels. At approximately elevation 16.5, water begins to rise over the docks. The SFOO will monitor the situation when it arises and relay pertinent conditions to the Water Management Section.

10. Fish and Wildlife Resources. Extreme low or high Lake Okeechobee water levels may completely dry out or inundate Lake Okeechobee’s littoral zone. At extreme high lake stage (greater than elevation 17), it has been documented that wind driven waves can cause large-scale loss of submerged and emergent plants by physical uprooting. When lake stages exceed elevation 15 for long periods, especially when light penetration is inhibited by turbid water, adverse impacts to submerged aquatic vegetation (SAV) can occur. Efforts should be made to prevent prolonged high (i.e. greater than elevation 15) and extreme high lake levels (i.e. greater than elevation 17), which should benefit wading bird foraging, nesting, spawning, and feeding habitat for fish.

Releases of freshwater from Lake Okeechobee along with other tributary inflows and stormwater runoff can cause large fluctuations in estuary salinity. A critical reproduction period for many estuarine dependent organisms is during the months of March through June. The volume, duration, and timing of freshwater inflow to estuaries is extremely important for the optimal balance of salinity. It is during the springtime that freshwater flows to the estuaries should be monitored closely and

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possibly reduced, so larvae are retained in the system and not flushed out by excessive freshwater flows. Freshwater releases should be monitored to aid in maintaining appropriate salinity conditions for reproduction.

In addition, it is important to note that various endangered/threatened species reside throughout the Central and Southern Florida (C&SF) Project area. The status of these Endangered/Threatened species and associated habitat(s) may influence and/or cause alteration/modification of water management operations for Lake Okeechobee and associated features contained within this document.

7-03. Overall Plan for Water Management.

2008 Lake Okeechobee Interim Regulation Schedule (2008 LORS). The water management operational criteria described in this water control plan establishes the allowable quantity, timing, and duration of releases from Lake Okeechobee to the WCAs and to tide (estuaries). Water management decisions will utilize the 2008 LORS Parts A through D (Figures 7-1 through 7-4) to provide guidance on releases from Lake Okeechobee. Information shown on Part A and Part B (Figures 7-1 and 7-2) is utilized to compare the Lake elevation and the corresponding band and sub-band, respectively. Information shown on Part C and Part D (Figures 7-3 and 7-4) is utilized to establish the allowable releases to the WCAs and the allowable releases to tide (estuaries), respectively.

When the operational criteria and/or basin conditions between Lake Okeechobee and the estuaries result in flows deemed undesirable by SFWMD to the estuaries, the SFWMD may seek to store Lake Okeechobee water on available SFWMD designated lands. As Comprehensive Everglades Restoration Plan (CERP) reservoirs designed to receive Lake Okeechobee releases become available, they will be operated according to the operational guidance established for those projects. These efforts are intended to reduce undesirable lake releases to the estuaries by first making lake releases to alternative storage areas to minimize flows that are above the estuary’s biologically-derived maximum flow criteria.

The decision-making process for Lake Okeechobee water management operations considers all Congressionally-authorized project purposes. The decision-making process to determine quantity, timing, and duration of the potential release from Lake Okeechobee includes consideration of various information related to water management. This information includes but is not necessarily limited to: C&SF Project conditions, historical lake levels, estuary conditions/needs, lake ecology conditions/needs,

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WCA water levels, STA available capacity, current climate conditions, climate forecasts, hydrologic outlooks, projected lake level rise/recession, and water supply conditions/needs.

For Lake Okeechobee, an environmental release can be considered as a release from Lake Okeechobee to benefit the lake ecosystem, downstream ecosystems, and/or upstream ecosystems. A base flow release to the Caloosahatchee Estuary is a release from Lake Okeechobee at S-77 to achieve a 450 cfs flow at S-79. A base flow release to the St. Lucie Estuary is a release at S-308 to achieve a 200 cfs flow at S-80. In addition, a water supply release can be considered a release from Lake Okeechobee to meet water supply demands (for ENP, salinity control, regional groundwater control, agricultural irrigation, municipalities, industry and the environment).

Part A of the 2008 LORS (Figure 7-1) can be considered a starting point in the decision-making process for Lake Okeechobee water management operations. Part A allows a quick visual determination of which of the general management bands (elevation guidelines) applies to the current lake stage. Use of the 2008 LORS Parts B through D (Figures 7-2 through 7-4) will result in the determination of releases from Lake Okeechobee. The elevation guidelines include appropriate variations by season to conform to competing project purposes. Recreation and navigation are provided for when water is available and/or through releases conducted for other project purposes. The procedure involved for application of the flowcharts contained on Parts C and D (Figures 7-3 and 7-4, respectively) is described in Appendix K.

The release to be implemented will be limited to the allowable release determined from Part C and Part D (Figures 7-3 and 7-4), except as noted in the Make-up Releases Section (Section 7-15). Releases can vary up to the allowable release based on consideration of current and anticipated conditions/needs as stated in paragraph 3 of this section (Section 7-03).

The Make-up Releases Section (Section 7-15) outlines the implementation of releases from Lake Okeechobee to tide and/or to the WCAs (via STAs) to make up for releases that were previously reduced or prevented. When the lake level is below the Intermediate Sub-Band, these make-up releases from Lake Okeechobee to tide (estuaries) and WCAs will occur as soon as possible and may occur when Parts C and D (Figures 7-3 and 7-4) do not allow for releases or prescribe a lower volume release.

Occasionally, Additional Operational Flexibility (Section 7-16) will be used to address circumstances (i.e., hydrologic conditions, lake levels, spawning in the estuaries and downstream

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runoff). Additional operational flexibility provides water managers the ability to consider releases from Lake Okeechobee to the WCAs and to tide (estuaries) to minimize damages or to meet project purposes when the 2008 LORS Parts A through D (Figures 7-1 through 7-4) are not effective at managing lake levels. Each event to be addressed by additional operational flexibility is unique and releases to be implemented will be defined by a desired outcome or time-period.

The proposed operational guidance for management of the Lake Okeechobee water levels and outlet canals (included in Table 7-1) has three distinct bands defined by seasonal fluctuations of the lake level (Figure 7-1). Each management band is designed to achieve specific objectives consistent with Congressionally-authorized purposes for Lake Okeechobee. The bottom band, at the lower lake levels, is the Water Shortage Management Band. In this band, water in Lake Okeechobee will be managed in accordance with the Water Shortage Plan established by SFWMD. Outlet canals may be maintained below their optimum water management elevations (Table 7-1) in this band. The top band, at the higher lake levels, is the High Lake Management Band. The goal for lake management within this band is to quickly lower high lake levels. This will make lake storage available for use during the next rainfall event, to reduce impacts on Lake Okeechobee's SAV, and to reduce the risk to public health and safety, including but not limited to HHD integrity issues; outlet canals may be maintained above their optimum water management elevations in this band. The middle and largest band is the Operational Band, which includes several sub-bands (High, Intermediate, Low, Base Flow, and Beneficial Use Sub-Bands). It is anticipated that the majority of time, lake levels will be within the Operational Band, and Lake Okeechobee would be managed according to the operational criteria established for the sub-bands of the Operational Band, including provisions to meet water supply demands (for ENP, salinity control, regional groundwater control, agricultural irrigation, municipalities, and industry). Outlet canals should be maintained within their optimum water management elevations in this band.

When operating near band and sub-band limits, up to 30-day forecasts will be made and releases will be scheduled to lower or maintain Lake Okeechobee at the desired level during the 30-day period. Scheduling of releases may include the adjustment of band/sub-band limits when determining the release to implement. Factors considered in adjusting the band/sub-band limits would include but not be limited to: availability of STA treatment capacity, SFWMD designated lands, CERP reservoirs, and the condition of tributary basins. The band/sub-band adjustment is meant to transition into and out of sub-bands by allowing flows to gradually increase or decrease between sub-bands. An example

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of this adjustment would be: a condition above is occurring, lake level is 0.2 feet below the Intermediate Sub-Band and projected to rise into the Intermediate Sub-Band, then the allowable Lake Okeechobee release would be determined by following Part D (Figure 7-4) with the lake level considered to be in the Intermediate Sub-Band (not 0.2 feet below the Intermediate Sub-Band).

The Corps expects to operate under the 2008 LORS until the earlier of (1) implementation of a new Lake Okeechobee Regulation Schedule as a component of the system-wide operating plan to accommodate the CERP Band 1 projects and the State of Florida's fast-track Acceler8 projects, or (2) completion of HHD seepage berm construction or equivalent dike repairs for reaches 1, 2 and 3.

7-04. Flood Control. Three main methods of flood control are employed to protect life and property adjacent to and downstream of Lake Okeechobee (C-43, C-44 and EAA). First, the HHD completely encircles the large lake except where it ties to high ground on either side of Fisheating Creek. Structures through HHD are closed completely far enough in advance of a hurricane or tropical storm to contain the lake for the duration of the storm event while not endangering operating personnel.

Second, an objective of the 2008 LORS is to manage the lake level on a seasonal basis to mainly provide for additional storage volume by lowering the lake's water level in advance of the wet season. This is an attempt to provide for storage of basin rainfall runoff in the lake while allowing the lake's outlet structures to discharge over a long period of time. This action may be needed because the lake's outlet capacity is very small compared to the immense storage capacity and drainage area that makes up the lake's basin/watershed. The outlet structures include S-308, Culvert 10A (C-10A), S-352, S-351, S-354, S-77 and various smaller culverts within HHD.

Third, the OWW canals and the EAA canals are maintained at optimum water levels as shown in Table 7-1 except for hurricane or tropical storm events or when the lake elevation is lower than optimum canal levels. Excess canal water may be sent to the lake, tide, STAs, or WCAs depending upon severity of rainfall event, water levels, etc. To maintain EAA canals at their optimum levels, EAA canal water is typically pumped into STAs or, if necessary during storm events, the WCAs. To maintain C-43 at its optimum canal levels, C-43 water downstream of S-77 is typically discharged to tide at S-79. If the lake water level is low enough, C-43 water upstream of S-78 may be sent to the lake via gravity. To maintain C-44 optimum canal levels, C-44 water downstream of S-308 is typically discharged to tide at S-80. If

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the lake is low enough, C-44 water upstream of S-80 may be sent to the lake via gravity using the S-308 spillway and/or lock.

a. <u>High Lake Management Band</u>. The High Lake Management Band, shown on Figures 7-1 and 7-2, varies seasonally between elevations 16.0 and 17.25 and above. The goal of this band is to reduce the risk to public health and safety and to make releases to lower the lake below the High Lake Management Band as soon as possible. In this High Lake Management Band, it is of the utmost importance that the lake level be reduced as rapidly as possible to make storage available for the next possible rainfall event, to relieve stress on the HHD, and to reduce impacts on Lake Okeechobee's littoral zone. Releases up to the maximum discharge capacity will be made to tide and up to maximum practicable discharges will be pumped to the WCAs and made available to CERP impoundments (as they become available). In an effort to reduce undesirable lake releases to the estuaries, Lake Okeechobee water will also be made available to the SFWMD for their use to store on lands designated by SFWMD (as they become available). Within the High Lake Management Band, the allowable release from Lake Okeechobee to the WCAs and to the estuaries is defined by the lake level as shown on Figures 7-3 and 7-4, respectively. Actual rates of release from Lake Okeechobee will vary depending on, but not limited to, downstream channel conditions, estuary conditions, conditions in the WCAs, and conditions in the STAs. Although unlikely to be required due to wet conditions that are likely to exist when lake levels are within this band, Lake Okeechobee releases to meet water supply demands (for ENP, salinity control, regional groundwater control, agricultural irrigation, municipalities, industry, and the environment) may be made at any time within the High Lake Management Band. The conditions displayed on the flowcharts (Figures 7-3 and 7-4) for High Lake Management Band releases are described as follows:

1. Pump maximum practicable flows to the WCAs via the EAA canals (West Palm Beach Canal, Hillsboro Canal, North New River Canal, and Miami Canal). This flow shall be secondary to use of these canals to relieve flooding from the local drainage area. Under the SPF, the maximum design discharge rate through each EAA canal when there is no local inflow is as follows:

West Palm Beach Canal	**1,250 cfs**
Hillsboro Canal	**800 cfs**
North New River Canal	**1,600 cfs**
Miami Canal	**<u>2,000 cfs</u>**
Total Capacity	**5,650 cfs**

The maximum tailwater elevation below S-351, S-352, and S-354 should not exceed 12.0 when the EAA canals convey Lake Okeechobee releases.

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2. Release up to 9,300 cfs from S-77 to the Caloosahatchee River (C-43). This flow shall be secondary to use of the river to first relieve flooding within the local drainage area. Lake releases will be made considering the peak inflow from the local drainage area while not exceeding 9,300 cfs at S-78.

3. Release up to maximum capacity (historically 7,300 cfs) from S-308 to the St. Lucie Canal (C-44). Releases shall be conducted to assure smooth transitions in flow that do not induce waves or excessively high peak discharges during changes in flow rates.

4. Release up to maximum capacity from C-10A to the L-8 canal and, eventually, C-51. This flow shall be secondary to use of the L-8 canal and C-51 to first relieve flooding within the local drainage area. Lake releases will be made considering the peak inflow from the local drainage area.

b. Operational Band. The largest management band varies seasonally between elevations 10.5 at its lowest point and 17.25 at its highest point. The goal of the Operational Band is to manage the lake stage to balance all Congressionally-authorized project purposes. This involves use of flood control releases, environmental releases, base flow releases, and water supply releases. In an effort to reduce undesirable lake releases to the estuaries, Lake Okeechobee water may be stored in CERP reservoirs (as they become available) or SFWMD may seek to store Lake Okeechobee water on available SFWMD designated lands. The Corps will coordinate operations with the SFWMD as necessary.

Within the Operational Band, several sub-bands have been established to further define lake releases. As described below, these bands include the Base Flow Sub-Band, Low Sub-Band, Intermediate Sub-Band, and High Sub-Band.

1. High Sub-Band. This sub-band varies seasonally between elevation 15.5 at its lowest point and elevation 17.25. In this sub-band, releases to the Caloosahatchee Estuary of up to 3,000 cfs measured at S-79, and up to 1,170 cfs to the St. Lucie Estuary measured at S-80, can always be made for management of the lake level. The allowable lake releases to the estuaries are defined by lake level, THCs, the projected rise of the lake, short-term weather forecasts, and the seasonal climate/hydrologic outlook as shown on Figure 7-4. The allowable release from Lake Okeechobee to the WCAs is defined by lake level and downstream WCA level(s), as shown Figure 7-3. The maximum allowable lake releases to the WCAs and estuaries is provided as follows:

Note: All elevations are in feet, National Geodetic Vertical Datum of 1929 (ft., NGVD) unless otherwise noted.

(a) To WCAs-When all downstream WCAs are less than a quarter of a foot above the maximum elevation of their regulation schedules, then up to maximum practicable release to the WCAs are allowable.

(b) To Estuaries-When THCs are very wet and the lake level is projected to rise into the High Lake Management Band, then lake releases up to maximum discharge capacity are allowable.

2. Intermediate Sub-Band. This sub-band varies seasonally between elevation 15.0 to elevation 16.88. In this sub-band, operations for base flow to the estuaries will be conducted consistent with the Base Flow Sub-Band. Lake Okeechobee releases to the estuaries that are greater than base flow are allowed within this sub-band and are defined by lake level, THCs, the projected rise of Lake Okeechobee, short-term meteorological forecasts, seasonal hydrologic outlooks, and climate-based hydrologic outlooks as shown on Figure 7-4. The allowable release from Lake Okeechobee to the WCAs is defined by lake level and downstream WCA level(s), as shown on Figure 7-3. The maximum allowable lake releases to the WCAs and estuaries is provided as follows:

(a) To WCAs-When all downstream WCAs are less than a quarter of a foot above the maximum elevation of their regulation schedules, then up to maximum practicable release to the WCAs are allowable. Downstream WCAs refer to the WCAs downstream of the WCA receiving Lake Okeechobee discharges. For example, if it is desired to make a release to WCA-3A (via STA-3/4), then WCA-1 and WCA-2A water levels do not constrain the release to WCA-3A since they are upstream of WCA-3A. However, if it is desired to make a release to WCA-2A (via STA-3/4), and if the WCA-3A water level was higher than a quarter of a foot above the maximum of its regulation schedule, then no release to WCA-2A would be made.

(b) To Estuaries-When tributary conditions are very wet and the lake level is projected to rise into the High Sub-Band, lake releases up to 6,500 cfs at S-77 and up to 2,800 cfs at S-80 (6,500/2,800) are allowable.

3. Low Sub-Band. This sub-band varies seasonally between elevations 13.0 and 16.25. In this sub-band, operations for releases to the WCAs and base flow to the estuaries will be conducted consistent with the Base Flow Sub-Band. Lake Okeechobee releases to the estuaries that are greater than base flow are allowed within this sub-band and

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are defined by lake level, hydrologic conditions, lake level's distance from the Intermediate Sub-Band, THCs, and climate-based hydrologic outlooks as shown on Figure 7-4. As shown on Figure 7-2, this sub-band was divided into thirds (Upper Range, Middle Range, Lower Range). Within the Upper Range, the pulse release to the Caloosahatchee Estuary is up to 3,000 cfs while to the St. Lucie Estuary it is up to 1,170 cfs (3,000/1,170) These pulse release values represent average flow rates to the Caloosahatchee and St. Lucie Estuaries, respectively. The pulse release in the Middle Range and the Lower Range is 2,500/950 and 2,000/730, respectively. Within the Low Sub-Band, the release from Lake Okeechobee to the WCAs is defined by lake level, THCs, effect of desired release on the Everglades, downstream WCA level(s), and the multi-seasonal climate-based hydrologic outlook as shown on Figure 7-3. The maximum allowable lake releases to the WCAs and estuaries is provided as follows:

(a) To WCAs-When THCs and the multi-seasonal climate/hydrologic outlook are not in their dry classifications, then up to maximum practicable release to the WCAs are allowable if the release is beneficial to, or will result in minimum Everglades' impacts. Both the quantity and quality of Lake Okeechobee water will be considered.
(b) To Estuaries-When tributary conditions are very wet, the lake level is within one foot of the Intermediate Sub-Band, and the seasonal climate forecast is very wet, then lake releases up to 4,000 cfs at S-77 and up to 1,800 cfs at S-80 (4,000/1,800) are allowable.
(c) To Estuaries-When the lake level is not within one foot of the Intermediate Sub-Band, or tributary conditions are not very wet, and the multi-seasonal climate/hydrologic outlook is wet, then lake releases up to 3,000 cfs at S-79 and up to 1,170 cfs at S-80 (3,000/1,170) are allowable. These releases are intended to be made in a pulse release that is sensitive to the estuary environment.

4. Base Flow Sub-Band. This sub-band varies seasonally between elevations 12.6 and 14.5. In this sub-band, the allowable release from Lake Okeechobee to the WCAs is defined by lake level, hydrologic conditions, effect of desired release on the Everglades, treatment capacity of STAs, downstream WCA level(s), THCs, and climate-based hydrologic outlooks as shown on Figure 7-3. Also in this sub-band, continuous, low-volume releases can be made to the Caloosahatchee Estuary and the St. Lucie Estuary. Base flow limits are defined as up to 450 cfs measured at S-79, and up to 200 cfs measured at S-80. If the

Note: All elevations are in feet, National Geodetic Vertical Datum of 1929 (ft., NGVD) unless otherwise noted.

basin runoff between Lake Okeechobee and the estuary is less than this “base flow”, then Lake Okeechobee releases are made to supplement the difference. These base flow releases of excess lake water may have environmental benefits to the estuaries and help to reduce the chances of subsequent high volume discharges. In addition, the SFWMD may allocate water to the environment through its “Adaptive Protocols” or other SFWMD authorities.

When conducting base flow releases, flows up to 650 cfs can be distributed East and West as needed to minimize impacts or provide additional benefits. Very dry Tributary Hydrologic Conditions (THCs) may require that releases to tide (estuaries) be discontinued.

c. Advance Flood Releases. No flood releases are required in the Water Shortage Management Band. However, occasional advance flood releases can be made during the late winter months with no loss of water supply benefits when operating within one-half foot below the top of the Base Flow Sub-Band. This should be done only when unusually wet conditions prevail, and weather forecasts predict more of the same.

d. Canal Regulations. Except for hurricane or tropical storm regulation or when lake levels drop below canal regulation levels, canals shall be regulated automatically or manually, insofar as possible, in accordance with optimum levels shown in Table 7-1, following the text. Canal design elevations and actual installed pump capacities may be found in Appendix A of the Master Water Control Manual, Lake Okeechobee and Everglades Agricultural Area, Volume 3, June 1996 (Master Water Control Manual), and will be different from optimum elevations in many cases. All of the pump stations were designed to remove ¾-inch runoff per day from the EAA. Note that SFWMD’s pump stations G-370 and G-372, which service the S-2, S-3, S-7 and S-8 basins, have the capability of removing larger volumes per day.

e. Release up to maximum capacity from C-10A to the L-8 canal and, eventually, C-51. This flow shall be secondary to use of the L-8 canal and C-51 to first relieve flooding within the local drainage area. Lake releases will be made considering the peak inflow from the local drainage area.

f. An effort should be made to discharge water at S-80 on an outgoing/low tide, and to reduce S-80 releases on an incoming/high tide such that the S-80 tailwater does not exceed 3.0 feet. This is due to the fact that the St. Lucie Settlement subdivision on the South Fork of the St. Lucie River experiences flooding during high rain events. The flooding can occur when rainfall in the subdivision, wind in the St. Lucie estuary/South Fork of the St. Lucie River, tidal surge, and/or S-80 discharges occur. Due to the potential for flooding, the S-80 tailwater should not exceed elevation 3.0 when the discharges are being conducted. This includes reducing ongoing discharges at S-80 and S-308 when storm-induced and/or daily tidal surge is expected to cause a S-80 tailwater elevation of 3.0 or above.

If S-80/S-308 discharges are absolutely necessary and the S-80 tailwater elevation is expected to exceed 3.0 as a result, then local emergency managers should be notified. The SFOO will notify the Martin County Emergency Operations Center.

g. Hurricane or Tropical Storm Regulations. These regulations may be supplemented, but not superseded, by emergency action plans contained in the Herbert Hoover Dike Lake Okeechobee Structures Draft Emergency Action Plan, July 2005, including S-351, S-352, S-354, S-193, S-310, S-77, S-78, S-79, S-80, S-308B, and S-308C. Also, for hurricane and tropical storm emergency response within the Corps' Jacksonville District, refer to CESAJ SOP 500-1-1 Emergency Operations - Standard Operating Procedure dated April 2007. These emergency action plans should be consulted for related emergency preparation and actions. Local emergency management offices should be notified as necessary.

1. The following structures will be manned by Corps personnel in radio contact with the Chief, SFOO, Clewiston, Florida:

(a) S-77 spillway and Moore Haven Lock
(b) Lock S-310 (Formerly HGS-2)
(c) Lock S-193 (Formerly HGS-6)
(d) S-308B&C (Port Mayaca Lock and Spillway)

The above named structures will be closed and will remain closed until permission is granted to open them by the Chief, SFOO. If radio contact is lost, the gates shall be closed and shall remain closed until contact is again resumed with the Chief, SFOO.

2. Corps personnel will inspect all flap gates on all culverts entering Lake Okeechobee and ensure that they are operating properly and that they will close automatically if the lake stage rises. All slide gates shall be closed. All locks in the lake levee shall be checked to make sure they are closed.

3. The emergency action plans prescribe the necessary procedures for rapid implementation of emergency actions to be taken. The SFOO and the Corps' Water Management Section, Water Resources Engineering Branch, Engineering Division, Jacksonville District will specify the operating range for these structures.

Note: All elevations are in feet, National Geodetic Vertical Datum of 1929 (ft., NGVD) unless otherwise noted.

The ranges stated below are based on past experience and are subject to change depending on local conditions. The canal stage may be drawn down to the low end of the range in advance of the storm event in order to use the canals to provide limited storage in anticipation of the possibility for above normal storm tides and rain. Conversely, the canal stage is allowed to rise to the high end of the range in order to reduce flood impacts downstream due to possible above normal high tides. Corps personnel will man these structures and release local inflows as necessary to maintain the indicated upstream elevation ranges:

(a) S-78	10.4 to 11.5
(b) S-79	2.5 to 2.8
(c) S-80	13.5 to 15.5

S-79 gates may be closed or the gate opening reduced as necessary in the judgment of the lockmaster to reduce the quantity of saltwater intrusion from the higher than normal storm tides. The gates will be opened as necessary when the upstream elevation exceeds the downstream elevation until optimum levels can again be maintained.

4. All existing discharges for lake regulation will be discontinued and will not be resumed until ordered by personnel of the Water Management Section.

5. SFWMD personnel shall man all pump stations and pump to maintain water levels headwater elevations indicated insofar as possible:

(a) G-370	9.0
(b) G-372	9.0
(c) S-2	10.0
(d) S-3	10.0
(e) S-4	10.0
(f) S-5A	9.0
(g) S-6	9.0
(h) S-7	9.0
(i) S-8	9.0
(j) S-127	12.0
(k) S-129	12.0
(l) S-131	12.0
(m) S-133	12.0
(n) S-135	12.0

Adjacent and nearby locks operated by SFWMD shall be closed until the storm has passed and the Chief, SFOO, Corps of Engineers, gives permission to resume normal operations.

Note: All elevations are in feet, National Geodetic Vertical Datum of 1929 (ft., NGVD) unless otherwise noted.

6. SFWMD shall close the following structures in advance of the storm and open them only as directed by the Chief, SFOO, Corps of Engineers.

(a) S-351
(b) S-352
(c) S-354

7. SFWMD shall place the following remotely operated (telemetry) structures on automatic operation and check them as soon as possible following the storm:

(a) S-47D
(b) S-71
(c) S-72
(d) S-84
(e) S-153
(f) S-154
(g) S-191
(h) S-169
(i) S-47B

8. SFWMD shall open S-76 in advance of the storm and leave it open to fluctuate with pumping operations until the storm has passed.

9. SFWMD shall close the following structures in advance of the storm and open them only as directed by the SFWMD's Director of Operations:

(a) S-5AE
(b) S-5AS

10. SFWMD shall open S-5AW as long as pumping capacity is available at S-5A or operate as directed by the SFWMD's Director of Operations.

h. Emergency Lock Operations During High Lake Okeechobee Stages. During very high lake stages, and to provide storage in anticipation of the possibility for above normal storm tides and rain, the locks in the Caloosahatchee River have been used to augment discharges from Lake Okeechobee when additional capacity is needed to lower the lake. Due to safety concerns, this operation should only be done on a very limited basis or during maintenance work. Since the locks were not designed for this type of operation, possible damage to the structure could result. Careful consideration should be taken to not exceed the Maximum Allowable Gate Openings (MAGO) curves and to keep the hydraulic jump on the apron to preclude possible impacts downstream of the structure. (See Herbert Hoover Dike System, Embankment and

Culvert Structures, Interim Emergency Action Plan, September 1994, Subplan C, Preventative Actions, Augmenting Discharges.)

The lock should be operated with the downstream gates opened first to full open position. The upstream lock gates should then be set to the required opening. The rate of opening should adhere to normal lock opening rates. To terminate lock releases, the upstream gates should be closed first, then the downstream gates. The lock discharges should be limited so the combined lock and spillway discharges do not exceed 9,300 cfs at Ortona (S-78) and Moore Haven (S-77). These gate operations should be noted on the operation logs provided to the Water Management Section and the United States Geological Survey. Mariners should be notified of the boat lockage schedule during the lock discharge period through a Notice to Navigation Interests.

7-05. Recreation. Recreation is an authorized project purpose for both the OWW and the C&SF Project. There are abundant recreational facilities within the project area, both private and public; however, no specific water management operations are required for this purpose. Lake and canal levels are not specifically managed for recreation, although lake levels do affect recreation facilities. For example, boat launching ramps, pleasure crafts, sightseeing vessels, bank, and small boat fishing are all influenced by lake levels.

7-06. Water Quality. Regulations for water quality are a function of the State of Florida. SFWMD, acting on behalf of the state, petitions the Corps for changes in flood control and navigation water management operations where it determines that water quality benefits may be achieved in the project area without significant loss of project benefits for the project's authorized purposes. These water management operations to improve water quality (environmental releases, water supply releases) may occur within the Operational Band. When the lake level is above the Water Shortage Management Band, low volume releases may be implemented as part of Additional Operational Flexibility (Section 7-16) in an effort to benefit water quality within the lake and/or downstream.

a. Caloosahatchee River. Occasionally, the SFWMD may request or the Corps may initiate releases from Lake Okeechobee to the Caloosahatchee River for water quality enhancement purposes. Primarily, this release for water quality enhancement is to reduce salinity at the Lee County Olga water supply treatment plant intakes above W. P. Franklin Lock. An additional reason, but much less frequent, is a similar request to break up algae blooms in the river.

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b. Estuarine Management. High volume discharges to the estuaries of nutrient rich freshwater can have adverse effects on water quality in the estuaries. In the Base Flow Sub-Band, releases of excess lake water may have environmental benefits to the estuaries and help to reduce the chances of future high volume discharges during higher lake stages. The Base Flow Sub-Band releases also provide a benefit of maintaining desirable salinity levels in the estuaries. Additionally, When the lake level is above the Water Shortage Management Band, low-volume releases may be implemented as part of the Additional Operational Flexibility (Section 7-16) to prevent high lake levels and possible future high discharges to the estuaries.

In an effort to reduce the impact of high volume lake releases to the estuaries, both estuaries will be monitored and releases made to balance the project purposes while minimizing negative impacts at the lake and the estuaries. This may include reducing and/or delaying lake releases based upon estuary conditions.

In an effort to reduce the impact of high turbidity levels on the downstream estuaries, the lake and the estuaries will be monitored and releases made to balance the project purposes while minimizing negative impacts at the lake and the estuaries. This may include reducing and/or delaying lake releases based upon estuary conditions.

c. Lake Okeechobee Ecology. When the lake level is above the Water Shortage Management Band, low volume releases may be implemented as part of Additional Operational Flexibility (Section 7-16) in an effort to reduce high turbidity levels within the lake. These low volume releases are meant to prevent high lake levels and possible future high volume discharges that send large quantities of turbid water to the estuaries over a short period of time. Releases will be made to balance the project purposes while minimizing negative impacts at the lake and the estuaries.

7-07. Fish and Wildlife. Several water management operations related to fish and wildlife preservation or enhancement have been adopted over the years. In the decision-making process for water management operations, fish and wildlife preservation or enhancement is often related to the following: lake level fluctuation, marsh preservation, pulse releases, mullet migration, endangered species preservation, and estuary management. When the lake level is above the Water Shortage Management Band, low-volume releases may be implemented as part of the Additional Operational Flexibility (Section 7-16) in an effort to benefit fish and wildlife within the lake and downstream.

High volume releases to the St. Lucie and Caloosahatchee Estuaries have resulted in documented negative effects on the estuarine ecology. Research has shown that even prolonged moderate releases transform the estuarine systems into freshwater habitats within three to four weeks. The dramatic and rapid changes in salinities, and associated siltation that occurs, can produce long-term negative effects on these estuaries. In addition, continuous flow releases at these levels tend to create critically low benthic oxygen situations at the transitional zone between the freshwater and the saltwater (Atlantic Ocean or Gulf of Mexico). High volume releases generate even more problems because of greater potential for environmental disruption and associated public concern. Releases are typically made because of the high risk of loss of life and property associated with high lake stages and hurricane-generated waves and tides. (Guide for the Management of High Stages of Lake Okeechobee, Alan Hall, SFWMD, May 1992)

In early 1988, the SFWMD developed a pulse release program which included multiple pulse options for managing the stage of Lake Okeechobee to avoid high discharges. A series of three pulse discharge levels was developed for the St. Lucie and Caloosahatchee Estuaries. These pulse releases were incorporated into Zones B, C and D of the Water Supply/Environment (WSE) Interim Regulation Schedule. The release concept in conjunction with the normal tidal cycles allowed the estuarine system to absorb the freshwater without drastic or long-term salinity fluctuations. The magnitude of the pulse releases was proportioned between the St. Lucie Estuary and the Caloosahatchee Estuary in relation to the size and sensitivity of each ecosystem. The Caloosahatchee Estuary is much larger in size and, hence, has a greater freshwater absorbing capacity than the St. Lucie Estuary. An additional concern with the estuaries was the extensive seagrass habitats of the Indian River Lagoon and San Carlos Bay. (Guide for the Management of High Stages of Lake Okeechobee, Alan Hall, SFWMD, May 1992).

The 2008 LORS no longer uses pulse discharge levels, rather defines a pulse release by their respective duration and average daily discharge (e.g. 15-day, 2000 cfs-average daily or 10-day, 3000 cfs-average daily). A pulse release attempts to simulate a natural rainstorm event within the basins. The receiving body should respond to the pulse release in a similar fashion as if a rainstorm had occurred in the upstream watershed. Because the watershed has the potential to receive a variety of rainfall events, an average flow rate is targeted for the duration of the desired pulse release. This means that the desired pulse release duration and daily releases will be determined based upon the actual rainfall event in the watershed.

The local basin runoff downstream of the lake is considered during implementation of pulse releases as part of the 2008 LORS. Specifically, inflow between S-308 and S-80 is added to the release at S-308 to provide a pulse release at S-80. Likewise, inflow between S-77 and S-79 is added to the release at S-77 to provide a pulse release at S-79. By referencing pulse releases at S-79, local basin runoff is considered when determining the necessary release at S-77. This achieves pulse releases that are more sensitive to the estuary. This operation is also consistent with the historic pulse release operation to the St. Lucie Estuary at S-80.

a. Beneficial Use Sub-Band: This sub-band varies seasonally between elevations 10.5 and 13.0 at its highest point. Fish and wildlife enhancement and/or water supply deliveries for environmental needs may involve conducting an environmental release from Lake Okeechobee through the SFWMD's "Adaptive Protocols" or other SFWMD authorities.

b. Lake Level Fluctuation. The Lake Okeechobee littoral zone has extensive marshes on the northwest and south shores of the lake. Adequate fluctuation is considered essential for the health of the marshes. The 2008 LORS, through the releases possible within the Operational Band, varies the lake level on a seasonal basis to provide for the multiple project purposes, including fish and wildlife. However, natural fluctuations in rainfall and manmade fluctuations induced by water use during dry periods can result in a much greater lake level variation than the 2008 LORS provides. Lower lake levels can benefit the littoral zones, allowing a natural improvement in fish and wildlife habitat.

c. Endangered Species. The littoral zone of Lake Okeechobee provides one of the largest habitats in south Florida for the snail kite (Bennetts and Kitchens, 1997) and it supports large populations of wading birds (Smith et al., 1995). Rare and endangered species known to occur or possibly occur in the project area are the Southern bald eagle, Florida everglade kite, Wood stork, American peregrine falcon, American alligator, Florida manatee, Florida panther, and the Okeechobee Gourd. Several pairs of Florida everglade kite nest in the marsh each year, drawn to the area by an abundance of the apple snail. The wood stork is known to feed in the Lake Okeechobee marsh during extreme drought. Except for the manatee, no specific operations have been identified to protect endangered species other than those identified for general fish and wildlife purposes. Specific water management operations exist to protect manatees. The objective is to eliminate Corps water control structure-related manatee mortalities. Structure operating

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criteria for all Jacksonville District water control structures are found in CESAJ SOP No. 1130-2-3 and included in Appendix G of the Master Water Control Manual, Lake Okeechobee and Everglades Agricultural Area, Volume 3, June 1996. Also see Table 7-2, Gate Opening Procedures for Manatees, following the text.

d. Estuarine Management. Several experimental estuary management plans have been approved in the past for the St. Lucie Estuary. SFWMD has continuing research programs in both the St. Lucie and Caloosahatchee Estuaries. It is the Corps' policy to support this type of research by permitting water management operations following coordination under the National Environmental Policy Act (NEPA) of 1969 and the Endangered Species Act (ESA) of 1973, as amended.

Historically, the planned Lake Okeechobee releases to tide (estuaries) have been subject to reduction or prevention by spawning in the estuaries. When these conditions have occurred in the past, Lake Okeechobee releases have been delayed or discontinued to prevent adverse effects in the estuaries. As part of the decision-making process for water management operations, Make-up Releases (Section 7-15) may be considered to benefit the estuaries.

7-08. Water Supply. Some of the beneficial uses that have been identified specifically in legislation or later approved plans are water supply for municipal and industrial use, for irrigation of agriculture, for ENP, for salinity control and dilution of pollutants in project canals, and for estuarine management. Water supply releases can occur in any band/sub-band of the 2008 LORS. However, these water supply releases may be restricted at the discretion of the SFWMD as outlined in the Water Shortage Management Band of 2008 LORS described below:

a. Water Shortage Management Band. This band varies seasonally between elevation 10.5 to 13.0 and below. Operations in this band are governed by the SFWMD's Lake Okeechobee Water Shortage Management (LOWSM) Plan. The goal of this band is to manage existing water supplies contained within Lake Okeechobee in accordance with SFWMD rules and guidance.

b. C-43/C-44 Water Supply Strategy. When the lake elevation drops below the optimum canal elevations in the C-43 and C-44 canals, the following strategy may be implemented to help meet water supply demands: When the stage in the St. Lucie Canal at the headwater of S-80 is 0.75 feet or greater than the headwater at S-308, S-308 will be operated to discharge water back into the lake until the headwater at S-80 recedes to 0.5 feet greater than that of S-308 headwater.

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When the S-77 tailwater is 1.0 foot or greater than the S-77 headwater, S-77 will be operated to discharge water back into the lake until the S-77 tailwater recedes to 0.75 feet greater than that of the S-77 headwater.

c. Navigation. Water supply releases are made to the Caloosahatchee River and St. Lucie Canal to maintain optimum canal levels. This often provides project depths sufficient for navigation. In addition, during extended dry periods or declared water shortage periods, the SFWMD typically requests that the Corps implement reduced hours of lockages on the OWW as part of their Water Supply Plan and the Drought Contingency Plan referenced in Appendix B of the Master Water Control Manual. Normally, lockages are conducted "on demand", which requires numerous cycles of lock water being released downstream of the lock. During reduced hours of lockages, water is conserved and saltwater migration upstream of S-79 is potentially reduced.

It is important to note that the SFWMD request for weekly allocation volume water supply deliveries may not be sufficient to maintain navigation depths in the OWW.

7-09. Hydroelectric Power. There are no hydroelectric power generators in service on the C&SF Project. A small generator adequate to serve the St. Lucie Lock and Spillway was in use until about 1970, when it was shut down to conserve water in Lake Okeechobee.

7-10. Navigation. The OWW traverses the state from the Atlantic coast to the Gulf of Mexico and includes the St. Lucie Canal, Route 1 and Route 2 across Lake Okeechobee, and includes the Caloosahatchee River. The authorized channel is 10 feet deep from Ft. Myers to the S.C.L. Railroad bridge at Tice; then 8 feet to the Intracoastal Waterway (IWW), Jacksonville to Miami, near Stuart. An alternate 6 feet deep channel in Lake Okeechobee follows the south shore from Clewiston to the St. Lucie Canal. Another channel 6 feet deep is maintained from the City of Okeechobee to Lake Okeechobee (Route 2) along the alignment of lower Taylor Creek. Datum and project depths are shown in Table 7-9 below.

Note: All elevations are in feet, National Geodetic Vertical Datum of 1929 (ft., NGVD) unless otherwise noted.

Table 7-9

Navigation Depths and Datum for OWW Project

Channel Segment	Project Depth in Feet	Project Datum in Feet, NGVD
Gulf of Mexico to Tice	10	-0.88
Tice to Ortona Lock	8	-0.88
Ortona Lock to Moore Haven Lock	8	10.06
Lake Okeechobee		12.56
Moore Haven to Clewiston	8	12.56
Clewiston to Port Mayaca		12.56
Across lake route (Route 1)	8	12.56
South shore route (Route 2)	6	12.56
Taylor Creek channel	6	12.56
Port Mayaca Lock to St. Lucie Lock	8	12.56
St. Lucie Lock to IWW	8	-0.10

In addition, during extended dry periods or declared water shortage periods, the SFWMD typically requests that the Corps implement reduced hours of lockages on the OWW as part of their Water Supply Plan and the Drought Contingency Plan referenced in Appendix B of the Master Water Control Manual. Normally, lockages are conducted “on demand”, which requires numerous cycles of lock water being released downstream of the lock. During reduced hours of lockages, water is conserved and saltwater migration upstream of S-79 is potentially reduced.

7-11. Drought Contingency Plan. The Drought Contingency Plan for Lake Okeechobee can be found in Appendix B of the Master Water Control Manual. SFWMD’s Water Supply Plans represent the majority of the water management related contents of the Drought Contingency Plan and can be found using the following links:

https://my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_ENVIROREG/PORTLET_RULESSTATUTESAND/TAB383534/40E%2021%20LOWSM%2011-19-07.PDF

https://my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_ENVIROREG/PORTLET_RULESSTATUTESAND/TAB383534/40E-22.PDF

7-12. Standing Instructions to Damtender. Standing Instructions to Damtender are found in Appendix E of the Master Water Control Manual.

7-13. Deviation From Normal Regulation. The Water Management Section is responsible for handling deviation requests and transmitting them through the District Commander to the Division Engineer for final decision. The District Commander is

Note: All elevations are in feet, National Geodetic Vertical Datum of 1929 (ft., NGVD) unless otherwise noted.

occasionally requested to deviate from normal regulation schedules. Prior approval for a deviation is required from the Division Engineer except as noted in subparagraph "a" below. Deviation requests usually fall into the following categories:

a. Emergencies. Examples of some emergencies that can be expected to occur at a project are: drowning and other accidents, failure of the operation facilities, chemical spills, treatment plant failures and other temporary pollution problems. Water control actions necessary to abate the problem are taken immediately unless such action would create equal or worse conditions. Districts must inform their division office as soon as practicable. Prepare written confirmation of the deviation and description of the cause and furnish it to the division water control manager. Divisions may develop forms to facilitate the reporting of emergency deviations.

b. Unplanned Minor Deviations. There are unplanned instances that create a temporary need for minor deviations from the normal regulation plan, although they are not considered emergencies. Construction accounts for the major portion of these incidents and typical examples include utility stream crossings, bridge work, and major construction contracts. Deviations are sometimes necessary to carry out maintenance and inspection of facilities. Requests for changes in release rates generally involve time periods ranging from a few hours to a few days. Each request is analyzed on its own merits. In evaluating the proposed deviation, consideration must be given to upstream watershed conditions, potential flood threat, condition of the lake, and alternative measures that can be taken. In the interest of maintaining good public relations, requests generally are complied with providing there are no foreseen adverse effects on the overall regulation of the project (or projects) for the authorized purposes. Approval for these minor deviations normally will be obtained from the division office by telephone. Written confirmation explaining the deviation and its cause will be furnished to the division water control manager.

c. Planned Deviations. Each condition should be analyzed on its own merits. Sufficient data on flood potential, lake and watershed conditions, possible alternative measures, benefits to be expected, and probable effects on other authorized and useful purposes, together with the district recommendation, will be presented by letter or telefacsimile to the division for review and approval.

7-14. Rate of Release Change. Control structures should be opened and closed gradually. This provides an even transition to the new flow regime and minimizes the hydraulic effects downstream. Special attention should be given to the MAGO curve

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for each structure to insure that the tailwater has a chance to build up before large-scale openings are made.

a. St. Lucie Canal. Because of its length and size, rapid changes in discharges through the St. Lucie Canal can result in large waves traveling back and forth over the length of the canal. The following rules have been established to reduce this effect and to avoid excessive instantaneous peak discharges due to the gate-opening procedure:

1. Under most conditions the lockmaster will make the gate change in half-foot increments each half-hour until the desired opening is reached.

2. When the rainfall measured at St. Lucie Lock exceeds 2 inches in 24 hours or when the headwater is rising rapidly, the Jacksonville District Office over the telephone will provide the lockmaster with a table showing the headwater elevations at which each succeeding half-foot increment can be made without exceeding the 125 percent rating. Under conditions of extreme local inflow this may prolong a gate change over a 2 or 3 day period. The 125 percent rating was developed using the St. Lucie Canal rating curve for steady flow without local inflow and without Port Mayaca Lock and Dam. The average Lake Okeechobee stage should be adjusted downward by the amount of the head loss across S-308C if S-308C is fully open. Otherwise, do not adjust the curve.

3. No change in the current gate setting will be made during a rising headwater until the change can be made without exceeding the 125 percent rating. An exception to this rule may be made when the headwater elevation at S-80 reaches 15.5. At this point, gate changes may be made as often and as wide as necessary to maintain the headwater. When the headwater begins to fall, apply rules (1) and (2) again. There should be no deviation from the above rules unless specifically ordered by the Jacksonville District Office or in cases where a larger gate opening is immediately necessary to prevent overtopping of the structure.

7-15. Make-up Releases. Historically, the planned Lake Okeechobee releases to tide (estuaries) have been subject to reduction or prevention by downstream conditions such as downstream local basin runoff, the tidal cycle, tidal storm surge and spawning in the estuaries. Similarly, planned Lake Okeechobee releases to the WCAs have also been limited by high water levels in the WCAs, STA treatment capacity limits, and limited or no conveyance capacity in the primary canals within the EAA. When these conditions have occurred in the past, the releases have been delayed or discontinued to prevent adverse effects downstream from Lake Okeechobee. To address this issue,

proposed operational guidance includes conducting releases from Lake Okeechobee to tide and/or to the WCAs (via STAs) to make up for releases that were previously reduced or prevented. When the lake level is below the Intermediate Sub-Band, these make-up releases from Lake Okeechobee to tide (estuaries) and WCAs will occur as soon as possible and may occur when Parts C and D (Figures 7-3 and 7-4) do not allow for releases or prescribe a lower volume release. The lake make-up releases to tide (estuaries) would be limited to a pulse release from Lake Okeechobee not to exceed 2,800 cfs measured at S-79, and 2,000 cfs measured at the St. Lucie Estuary. This 2,000 cfs at the St. Lucie Estuary includes releases from all C&SF Project structures that discharge into the St. Lucie Estuary.

7-16. Additional Operational Flexibility. The 2008 LORS is not developed to optimize performance of any single project purpose, but rather attempts to balance the performance of the multiple project purposes. It is anticipated that future events similar to those experienced over the period of record (1965-2000) will be effectively managed by the 2008 LORS. The 2008 LORS was also simulated for the 2001 through 2005 period, and deemed effective for managing high lake elevations under this set of conditions. Occasionally, additional operational flexibility will be used to address circumstances (i.e., hydrologic conditions, lake levels, spawning in the estuaries and downstream runoff) that were not evaluated for the period of record. Additional operational flexibility provides water managers the ability to consider releases from Lake Okeechobee to the WCAs and to tide (estuaries) to minimize damages or to meet project purposes when the 2008 LORS Parts A through D (Figures 7-1 through 7-4) are not effective at managing lake levels consistent with the intent of the 2008 LORS.

Release decisions will take into account the estuary's biologically-derived maximum flow, future water supply demands, C&SF Project system-wide conditions, and lake ecological conditions, as appropriate. Consideration of the concern for public health and safety is the Corps' highest priority. Once implemented, releases will be discontinued when the conditions that prompted them have ceased or the desired outcome is achieved. Based upon the evaluation of historical conditions and the expected performance of the 2008 LORS, it is anticipated that use of additional operational flexibility will be infrequent.

Each event to be addressed by additional operational flexibility is unique and releases to be implemented will be defined by a desired outcome or time-period. The public will be notified of the planned releases, desired outcome, and implementation time period by the Corps' normal water management notification process (press release, internet webpage). The

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following sections identify the scenarios that would trigger the use of additional operational flexibility and provide details on releases to be considered under each scenario.

Additional operational flexibility will be used to address circumstances which were not evaluated in the 2008 LORS period of record, such as the following:

a. Undesirable/Prolonged High Lake Levels. Releases may be considered to prevent anticipated high lake levels or to lower high lake levels, in order to reduce risk to the HHD and to prevent additional adverse environmental impacts to Lake Okeechobee. In 2003, continuous high lake levels (above elevation 15 in excess of 13 months) resulted in a Temporary Deviation. The purpose of this Temporary Deviation was to minimize the risk of high lake levels, to lower Lake Okeechobee for prevention of additional adverse impacts in the lake and to reduce the potential of high-volume continuous releases to the estuaries. These intended purposes were accomplished while balancing other management objectives of water supply and flood control.

In the event that there are ongoing or planned activities at C&SF Project features (including CERP Projects) upstream or downstream of Lake Okeechobee, and high lake levels are projected to occur or anticipated to occur as a result of these activities and based on any combination of planned water management operations, climate forecasts, and historical information/data, then additional releases to the WCAs and to tide (estuaries) could be considered. All project purposes will be considered. When possible, the lake releases to tide (estuaries) would be limited to a pulse release from Lake Okeechobee not to exceed 2,800 cfs measured at S-79 and 2,000 cfs measured at the St. Lucie Estuary. This 2,000 cfs includes releases from all C&SF Project structures that discharge into the St. Lucie Estuary. Releases to the WCAs would depend on available treatment capacity in the STAs.

Additional releases might be implemented to lower Lake Okeechobee's level in advance of planned activities and/or to prevent high lake levels. An example is a planned muck removal operation involving a lake drawdown in the Kissimmee River Basin that could result in the need to create storage in Lake Okeechobee prior to the planned Kissimmee River Basin drawdown.

b. Climate Conditions. In the event that climate conditions, including but not limited to, El Nino, La Nina, and/or active hurricane season forecasts, are projected to create or continue high lake levels, additional operational flexibility would allow releases to WCAs and to tide (estuaries) to be

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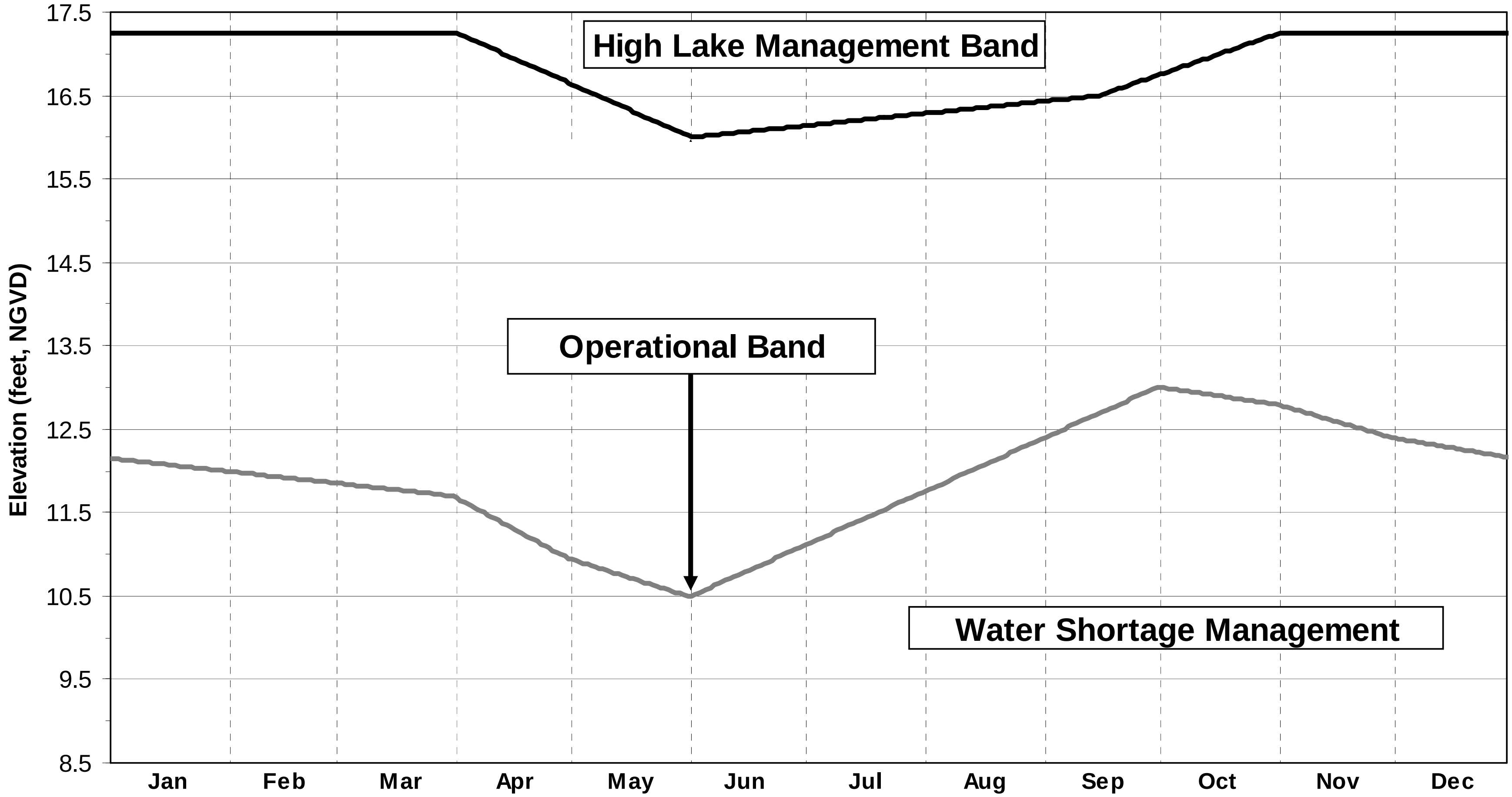
implemented. The lake releases to tide (estuaries) should be limited to a pulse release from Lake Okeechobee not to exceed 2,800 cfs measured at S-79 and 2,000 cfs measured at the St. Lucie Estuary. This includes releases from all C&SF Project structures that discharge into the St Lucie Estuary. The wet spring of 2004 (normally the dry season) and an overly active hurricane season are examples of conditions that could be addressed with additional operational flexibility.

c. Low Volume Releases. In the event that the lake level is above the Water Shortage Management Band and conditions exist that would require low-volume releases, additional operational flexibility would allow low-volume releases to be implemented. The low-volume releases would be implemented to address conditions including, but not limited to the following: to prevent and/or to lower high lake levels, to address algal blooms, to disperse saltwater in the river and/or estuary, or improve other conditions related to the Congressionally-authorized project purposes. The proposed low-volume releases would be limited to a pulse release from Lake Okeechobee of up to 2,000 cfs measured at S-79 and up to 730 cfs measured at S-80.

As an example, a Low Volume Release operation occurred in 2004. Operations were conducted that included a pulse release that averaged up to 1,600 cfs to the Caloosahatchee Estuary and up to 730 cfs measured at S-80. The purpose of these operations was to minimize the risk of high lake levels, to lower Lake Okeechobee for prevention of additional adverse impacts in the lake and to reduce the potential of high constant releases to the estuaries. These intended purposes were accomplished while balancing other management objectives of water supply and flood control.

FIGURES



NOTES:

High Lake Management Band: Outlet canals may be maintained above their optimum water management elevations.
Operational Band: Outlet canals should be maintained within their optimum water management elevations.
Water Shortage Management Band: Outlet canals may be maintained below optimum water management elevations.

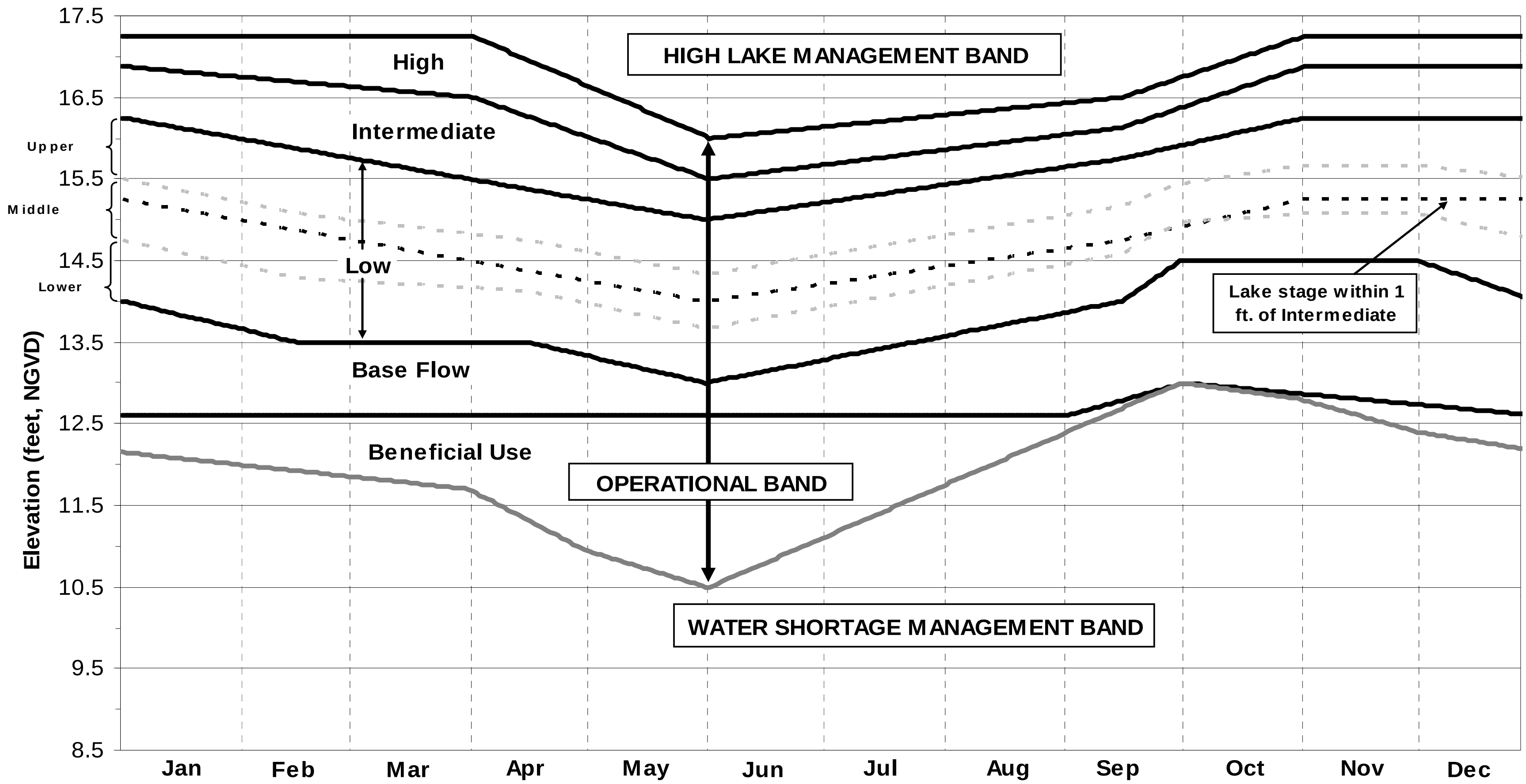
CENTRAL AND SOUTHERN FLORIDA PROJECT

2008 LAKE OKEECHOBEE
INTERIM REGULATION SCHEDULE

PART A

DATED: March 2008
DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

Figure 7-1



NOTES:

High Lake Management Band: Outlet canals may be maintained above their optimum water management elevations.

Operational Band: Outlet canals should be maintained within their optimum water management elevations.

Water Shortage Management Band: Outlet canals may be maintained below optimum water management elevations.

CENTRAL AND SOUTHERN FLORIDA PROJECT

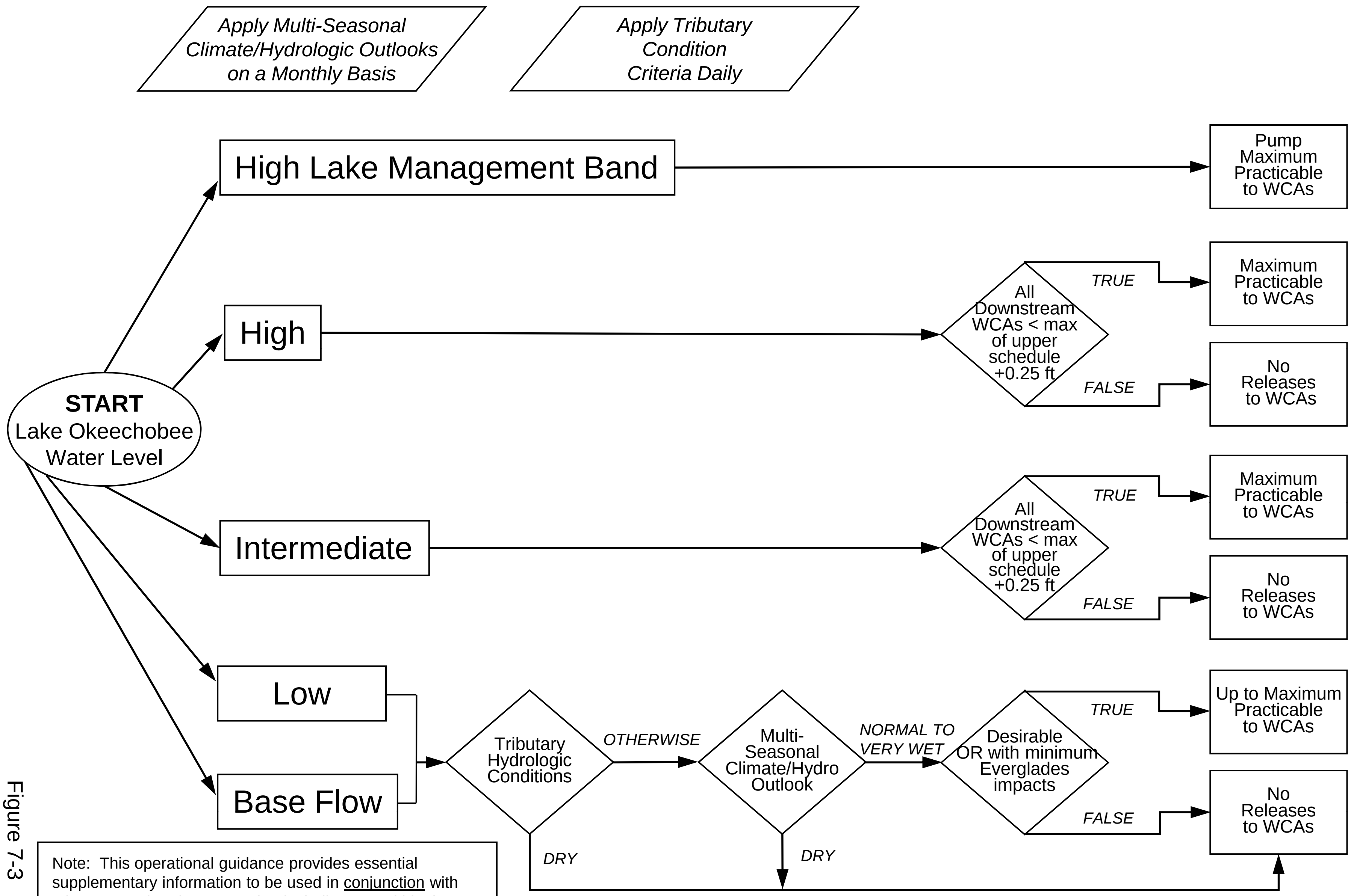
2008 LAKE OKEECHOBEE
INTERIM REGULATION SCHEDULE
PART B

DATED: March 2008
DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

Figure 7-2

2008 LORS

Part C: Establish Allowable Lake Okeechobee Releases to the Water Conservation Areas



Note: This operational guidance provides essential supplementary information to be used in conjunction with other supporting documentation including text within the Water Control Plan.

Figure 7-3

2008 LORS

Part D: Establish Allowable Lake Okeechobee Releases to Tide (Estuaries)

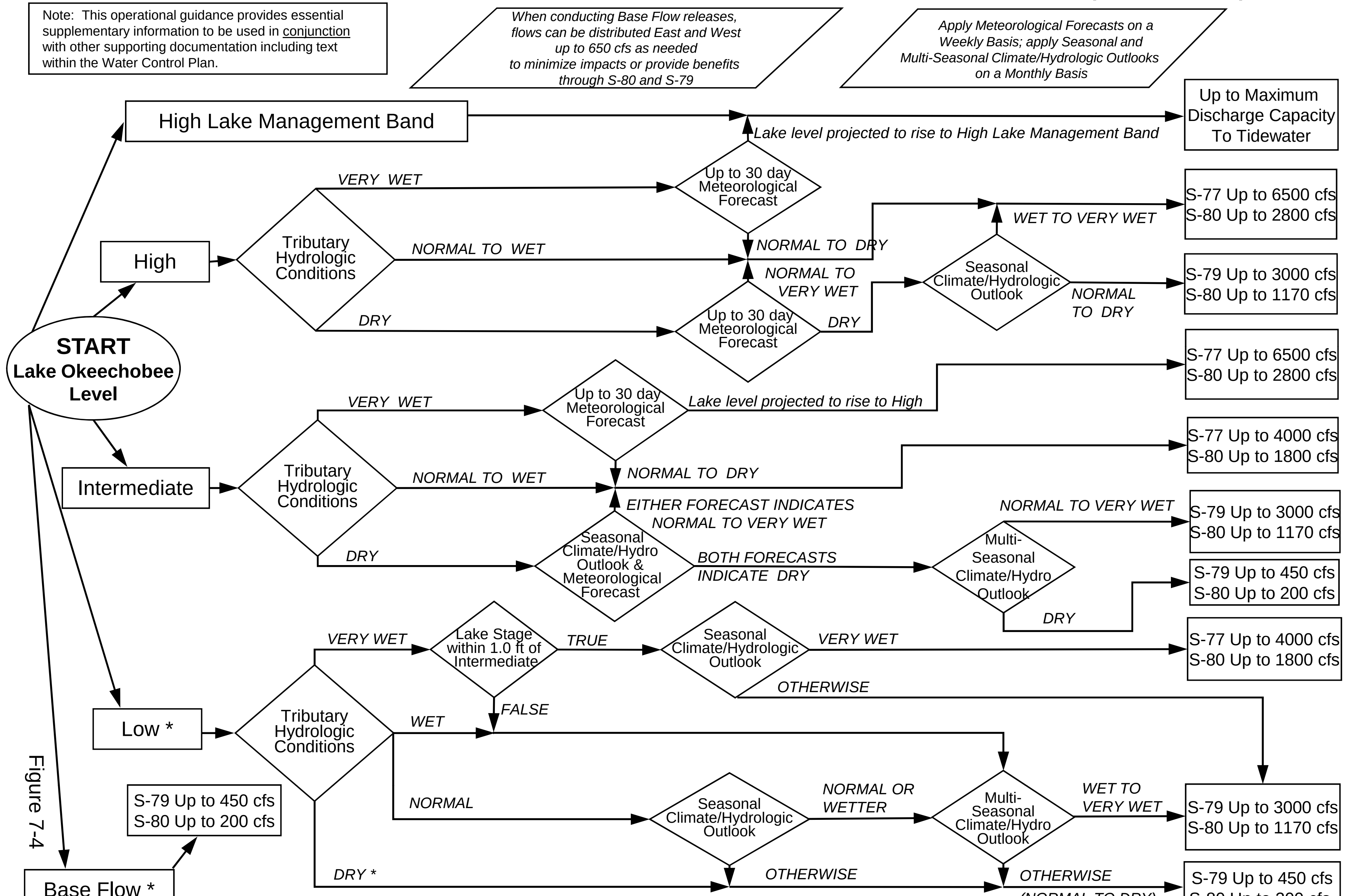


Figure 7-4

***** Very Dry Conditions may require that releases to tide (estuaries) be discontinued***

TABLES

WATER CONTROL PLAN TABLES

Table 7-1

Optimum Water Control Elevations

Structure	Canal Name	Optimum water-control elevation (ft., NGVD)
Culvert 10A (C-10A)	Levee and Canal 8	12.0 – 14.0
S-2	Hillsboro & N. New River	11.5 - 12.0
S-3	Miami Canal	11.5 - 12.0
S-4	Canal 20	13.0
S-5A	West Palm Beach Canal	11.5 - 12.0
S-5AE	Levee and Canal 8	---- (1)
S-5AW	Levee and Canal 8	---- (1)
S-5AS	Levee and Canal 8	---- (1)
S-5AX	Levee 13 Borrow Canal	---- (2)
S-6	Hillsboro Canal	11.5 - 12.0
S-7	N. New River Canal	11.5 - 12.0
S-8	Miami Canal	11.5 - 12.0
S-47D	Canal 19	12.3 - 12.9
S-47B	Canal 19	13.0 - 15.0
S-65E	Canal 38	---- (3)
S-71	Canal 41	---- (3)
S-72	Canal 40	---- (3)
S-76	Levee and Canal 8	---- (1)
S-77	Lake Okeechobee	---- (4)
S-78	Canal 43	10.6 - 11.5
S-79	Canal 43	2.8 - 3.2
S-80	St. Lucie Canal	14.0 - 14.5
S-84	Canal 41A	---- (3)
S-127	L-48 Borrow Canal	13.0 - 14.0
S-129	L-49 Borrow Canal	13.0 - 13.5
S-131	L-50 Borrow Canal	13.0 - 13.5
S-133	L-D4 Borrow Canal	13.0 - 14.0
S-135	L-47 Borrow Canal	13.0 - 14.0
S-153	L-65 Borrow Canal	18.6 - 19.1
S-154	L-62 Borrow Canal	23.0 - 24.0
S-169	Industrial Canal	15.0 (5)
S-191	C-59 and L-63(N) and L-63(S) Borrow Canals	19.0
S-192	Taylor Creek	19.0
S-235	L-D1 Borrow Canal Connector	13.0
S-236	Bare Beach Drainage District	13.0
S-308C	Lake Okeechobee	---- (4)

Notes:

(1) Same as WCA No. 1.
(2) Divide structure between drainage areas.
(3) Refer to Volume 2, Kissimmee River - Istokpoga Basin.
(4) Same as Lake Okeechobee.
(5) Same as Lake Okeechobee when lake is below 15.5.

Table 7-2

Gate Opening Procedures for Manatees

1. Lock Operations. The following standard operating procedures are in effect for safely locking manatees at St. Lucie Lock, Port Mayaca Lock, Moore Haven Lock, Ortona Lock and W.P. Franklin Lock:

a. Lock operators will be attentive as to the location and number of manatees in the lock chamber and approaches at all times, as well as aware that manatees may be present even if not visible.

b. Manatee sightings will be recorded on a Florida Department of Environmental Protection Manatee Sighting Form. These forms are to be submitted monthly to the Florida Department of Environmental Protection, Office of Protected Species Management, 3900 Commonwealth Boulevard, MS 245, Tallahassee, Florida, 32399-3000, with the SFOO retaining a file copy for record.

c. Every effort will be made to avoid hindering the passage of manatees through the locks and to assure their safety around vessels. Special lockages will be provided for manatees that demonstrate a desire to pass in a particular direction. According to the judgement of the lock operator on duty, vessels may be locked with manatees or delayed until the next lockage. At the W.P. Franklin Lock it will be necessary to turn off the bubbler system to allow manatees to enter and exit the lock chamber.

d. When manatees are first observed in the lock area, lock operators will inform approaching vessels of any manatees in the area and their locations, so craft can use extra caution. Lock operators will then assure that vessels are at idle speed upon entering the approach channels and inform vessels of any manatee movements necessary to their safety.

e. Every effort will be made not to crowd manatees in the lock chamber, especially with barges and tugs. Sufficient distance between vessels and gates will be maintained at all times.

f. Precautions will be made to assure manatee safety around sector gates. Operate sector gates at slowest speeds possible for the first minute to avoid manatees being trapped in strong currents. Operate both sector gates simultaneously; leaving one gate closed for any reason other than an emergency or malfunction should be avoided.

g. Delay vessels or lockage temporarily if imminent danger to a manatee exists by continuing operations. When locking manatees and vessels together delay vessels after lockage to assure

Table 7-2 (continued)

manatees enough time to clear the area and gain access to safe water. Vessel operators should then be warned to proceed with caution at idle speed. If there is doubt that the manatee has exited the chamber, the gates shall be left open to assure safe passage.

h. The SFOO will perform inspections of manatee exclusion screening devices on lock gates every 6 months and any time damage is suspected. Deficiencies will be corrected as soon as possible.

2. Flood Control/Spillway Gate Operations. The following standard operating procedures, in conjunction with the operating criteria contained in the approved water control plans and manuals for the Central and Southern Florida Project, are designed to reduce manatee risk during spillway operations. These procedures, however, are not intended for use at structures where manatee barriers (whether temporary or permanent) prevent manatee access to the spillway gates. The procedures below should only be used at spillways without barriers, or at spillways where barriers have been removed or are otherwise not fully functional. At spillways where barriers are functional and prevent manatee access to the spillway gates, gates should be operated in accordance with the operating criteria set forth in the water control plans and manuals.

a. Standard operating procedure for S-78, Ortona; and S-80, St. Lucie. The following procedures are designed to put the manatee at less risk during spillway operations and are based on the water surface profile (difference between the upper and lower pools) of the S-78 spillway (9' to 11') and S-80 spillway (12' to 14').

(1) On initial gate openings stop gate for 30 second period upon first sign of water movement. (Approximately .01 to .03 feet).

(2) Stop at .05' increments for 30 seconds until a .3' opening is acquired. Observe for a continuous flow across the full gate width at each increment.

(3) Continue opening gate in increments not to exceed .3' until gate is at desired opening. Operator will continuously observe for obstructions in gate opening during this procedure.

(4) If voids appear (interruptions of even water flow across the full gate width) the operator will determine to the best of his/her ability the source of the voids and make the following decision.

Table 7-2 (continued)

(a) If it appears to be trash or debris that is caught in the gate (aquatic plants, trees or other such debris) the operator will continue to open the gate at .3' increments at 30 second periods until the debris has passed through the gate and then lower the gate at .3' increments at 30 second periods until the desired gate setting is obtained.

(b) If it appears that a manatee has been entrapped, the gate should be operated as follows: If the current gate opening is less than or equal to 0.6 feet, the gate is to be closed to a height of 0.3 feet so that the manatee will be able to free itself. The gate may then be raised to the desired opening; this raising should be done in increments not to exceed 0.3 feet and with continual observations for obstructions. However, if the current gate opening is greater than 0.6 feet, then the gate should be immediately opened to allow the manatee to be washed through (up to a maximum of 2.5 feet) and then adjusted to the desired opening.

(5) Gates will always be maintained at the smallest possible opening across all gates. The minimum gate opening when more than 1 gate is in operation, will be .5 feet. This will allow debris to be flushed through the gate without being caught. The maximum single gate openings will be .9 feet.

(6) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operation procedures for manatee protection described herein.

b. General rule for operating single or multiple gates at S-77, S-79, S-308, S-351, S-352, and S-354, when the difference between headwater and tailwater elevations, or head, across these structures is less than or equal to 3.0 feet.

(1) To allow manatees to pass under the gates, the minimum opening for any gate under the "less than or equal to 3.0 feet of head" condition is 2.5 feet. One or more gates may be opened to 2.5 feet, subject to the following constraints: The operator should open the more central gates of the structure first, proceeding outward to those gates further from the center. The operator should also open gates on alternating sides of the structure. Thus, if there are four gates numbered 1-4 from left to right, a correct sequence for opening them would be: Gates 2, 3, 1, and 4. An equally correct sequence would be: Gates 3, 2, 4, and 1. Gates should be closed in reverse order.

Table 7-2 (continued)

(2) Gate openings greater than 2.5 feet should not be made until all gates have been opened to 2.5 feet, at which time additional gate openings may be made as follows: The operator may increase each gate opening in equal increments, in turn, in accordance with the Maximum Allowable Gate Opening (MAGO) curves until the predetermined opening is attained. At the end of the gate opening sequence, all of the gates must be set at approximately equal gate openings, all in accordance with the MAGO curves. As a practical consideration the spillway gates should not be adjusted such that gate openings differ by more than one foot.

(3) This procedure should be used at S-77 only if the tail water is above +9.0 feet, NGVD; and at S-79 only if the tail water is above -2.0 feet, NGVD. In other words, in the rare event that these conditions are not met, do not exceed the maximum allowable gate opening criteria.

(4) Gate openings greater than 2.5 feet shall be accomplished according to the operational criteria specified in the approved water control plans and manuals for the Central and Southern Florida Project.

(5) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operating procedures for manatee protection as described herein.

(6) The procedures above are only applicable for heads less than or equal to 3.0 feet. Procedures for heads exceeding 3.0 feet are described in the paragraphs that follow. If, while operating under the low head procedures above, the head across the structure should exceed 3.0 feet, the following steps should be taken: The gates should be closed, in reverse order, to openings permitted by the Maximum Allowable Gate Opening (MAGO) curves. The operating procedures applicable to heads greater than 3.0 feet should then be used.

c. General rule for operating a single gate at S-77, S-79, S-308, S-351, S-352, and S-354, provided that the difference between headwater and tailwater elevations, or head, across these structures is greater than 3.0 feet.

(1) If it is predetermined that an opening smaller than or equal to 2.5 feet would be needed for the gate:

Table 7-2 (continued)

The gate may be initially opened to a maximum of 2.5 feet and held at that opening for up to one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity while the gate is at the 2.5-foot opening. Within the one minute period, the gate must be closed to the predetermined opening. If the predetermined opening is not permitted by the Maximum Allowable Gate Opening (MAGO) curves, the operator must close the gate to a permitted opening and wait until the discharge raises the tailwater elevation so that the opening can be increased to the predetermined opening in accordance with the MAGO curves.

(2) If it is predetermined that an opening larger than 2.5 feet would be needed for the gate:

The gate may be initially opened to a predetermined opening larger than 2.5 feet, provided that such an opening would be permitted by the Maximum Allowable Gate Opening (MAGO) curves. If the predetermined opening would not be permitted by the MAGO curves, the gate may be initially opened to 2.5 feet and held at that opening for up to one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity while the gate is at the 2.5-foot opening. Within the one minute period, the operator must close the gate to a permitted opening in accordance with the MAGO curves and wait until the discharge raises the tailwater elevation. As the tailwater rises, the gate opening may be increased to the predetermined opening in accordance with the MAGO curves.

(3) This procedure should be used at S-77 only if the tail water is above +9.0 feet, NGVD; and at S-79 only if the tail water is above -2.0 feet, NGVD. In other words, do not exceed the maximum allowable gate opening criteria in the rare event that these conditions are not met.

(4) Gate openings greater than 2.5 feet shall be accomplished according to the operational criteria specified in the approved water control plans and manuals for the Central and Southern Florida Project.

(5) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operating procedures for manatee protection as described herein.

Table 7-2 (continued)

d. General rule for operating multiple gates at S-77, S-79, S-308, S-351, S-352, and S-354, provided that the difference between headwater and tailwater elevations, or head, across these structures is greater than 3.0 feet.

(1) If it is predetermined that an opening smaller than or equal to 2.5 feet would be needed for the gates:

One gate may be initially opened to a maximum of 2.5 feet and held at that opening for up to one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity of the gate. Within the one-minute period, the gate must be closed to the predetermined setting. If the predetermined opening would not be permitted by the Maximum Allowable Gate Opening (MAGO) curves, then the operator must lower the gate to a permitted smaller opening. This same procedure would then be repeated for opening the remaining gates. As the tailwater rises because of the discharge, the operator may increase each gate opening in equal increments, in turn, in accordance with the MAGO curves until the predetermined opening is attained. At the end of the gate opening sequence, all of the gates must be set at approximately equal gate openings, all in accordance with the MAGO curves. As a practical consideration the spillway gates should not be adjusted such that gate openings differ by more than one foot.

(2) If it is predetermined that an opening larger than 2.5 feet would be needed for the gates:

One gate may be initially opened to a predetermined opening larger than 2.5 feet, if such an opening would be permitted by the Maximum Allowable Gate Opening (MAGO) curves. The remaining gates must also be opened to the same opening. If the MAGO curves do not permit a 2.5-foot opening, one gate may be opened to 2.5 feet and then closed to a permitted opening within a maximum period of one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity while the gate is at 2.5-foot opening. This same procedure must be repeated for opening the remaining gates. As the tailwater rises because of the discharge, the operator may increase each gate opening in equal increments, in turn, in accordance with the MAGO curves until the predetermined opening is attained. At the end of the gate opening sequence, all of the gates must be set at approximately equal gate openings, all in accordance with the MAGO curves. As a practical consideration the spillway gates should not be adjusted such that gate openings differ by more than one foot.

Table 7-2 (continued)

(3) This procedure should be used at S-77 only if the tail water is above +9.0 feet, NGVD; and at S-79 only if the tail water is above -2.0 feet, NGVD. In other words, do not exceed the maximum allowable gate opening criteria in the rare event that these conditions are not met.

(4) Gate openings greater than 2.5 feet shall be accomplished according to the operational criteria specified in the approved water control plans and manuals for the Central and Southern Florida Project.

(5) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operating procedures for manatee protection as described herein.

3. Culvert Operations. The following standard operating procedures are in effect to reduce manatee risk at Herbert Hoover Dike and these extension levee Culverts; 1, 1-A, 2, 3, 4-A, 5, 5-A, 6, 8, 10, 10-A, 11, 12, 12-A, 13, 14, 16, and the following pipe culverts 1 (L-50); 1, 2, 3, 4, 5, 6 (Harney Pond Canal); 1, 2, 3 (Indian Prairie Canal); 1, 2, 3, 4 (Kissimmee River) and (50) pipe culverts on C-43, Caloosahatchee River, C.M.P. with risers.

a. When the vertical lift gates are being opened from the closed position, they will be raised to an initial opening of 2.5 feet and then closed to the desired setting. This will allow a resting manatee to be flushed through the culvert rather than being pinned and drowned at the point of the gate opening.

b. When the flap gate culverts are being opened by winch or crane, the shape of the flap gate and the slow operation will alert the manatee to move before a strong current could trap it at the point of the gate opening.

c. If manatees are observed during culvert operations, they will be discouraged from passing through to the smaller canal system in order to prevent entrapment in shallow water, possible harassment in developed areas and potential starvation.

Table 7-3

Monthly lake Okeechobee Net Inflow Data
(Equivalent Lake Depth, in inches: Volume-depth conversion based on average Lake surface area of 467,000 acres)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1913	1.67	5.40	4.24	4.24	-6.37	-1.57	1.77	1.49	2.44	-5.47	1.36	1.10	10.30
1914	-1.52	-1.98	0.21	0.08	1.18	-2.57	-0.33	-1.64	14.18	2.44	2.44	0.03	12.52
1915	1.10	-0.23	-0.33	-0.39	3.16	3.85	6.30	6.37	6.45	4.14	3.62	1.08	35.12
1916	0.90	-1.90	-2.24	-2.47	-0.80	2.78	7.27	1.31	2.49	1.26	3.67	0.00	12.27
1917	-5.04	-1.67	-1.75	-5.40	-3.13	0.13	3.47	5.91	1.41	-0.72	-5.40	-3.19	-15.38
1918	1.10	2.24	1.16	-1.05	-0.03	2.16	2.16	4.47	3.47	-0.82	-2.03	-1.05	11.78
1919	1.03	-0.08	-2.24	1.98	4.21	3.47	5.68	5.96	3.73	1.44	2.70	0.33	28.21
1920	1.88	0.64	0.59	-0.59	1.67	4.03	4.24	4.39	1.52	5.11	1.59	-1.28	23.79
1921	-0.28	-1.62	-1.75	-0.67	1.62	0.44	-1.98	-2.03	-2.00	1.39	3.75	1.46	-1.67
1922	-0.95	-5.40	-2.24	-3.26	2.93	1.26	4.52	7.89	27.21	14.90	1.85	1.72	50.43
1923	-0.23	1.98	-5.88	-4.73	2.36	5.99	4.91	5.04	5.22	-4.47	-4.57	0.18	5.80
1924	0.18	0.54	-3.52	-2.62	-5.32	0.54	4.70	-2.47	8.25	24.51	10.92	7.37	43.08
1925	7.14	6.58	2.52	2.98	1.10	3.34	4.75	9.92	1.34	2.98	1.46	6.32	50.43
1926	9.84	4.68	0.82	4.16	0.26	7.45	10.46	8.58	18.96	10.79	6.12	5.40	87.52
1927	-0.93	1.28	-5.40	-5.16	1.59	0.36	-2.13	0	2.13	0.00	-4.27	1.05	-11.48
1928	-2.08	-0.98	-3.96	-2.93	0.00	2.00	15.44	30.6	23.90	7.30	4.37	1.05	74.69
1929	0.46	-1.05	2.42	-1.77	-1.54	1.34	4.42	2.34	18.42	16.29	4.27	2.42	48.02
1930	2.49	4.47	1.62	3.73	7.97	49.95	16.73	7.01	13.82	11.10	1.93	5.45	126.27
1931	4.88	3.01	8.12	6.14	0.75	-5.01	-2.29	2.83	8.51	1.57	-2.83	-0.98	24.70
1932	0.00	-0.51	-1.80	-3.31	-0.28	7.25	-1.31	12	5.09	-1.28	6.86	-2.06	20.60
1933	-0.64	-3.85	1.54	2.93	-1.59	2.06	2.26	10.1	21.40	14.52	5.01	0.54	54.23
1934	0.64	1.34	3.73	-0.10	2.47	10.66	16.14	14	12.80	5.19	1.49	-0.26	68.10
1935	-0.62	-0.77	-3.85	3.70	-2.62	2.54	0.03	2.36	13.59	8.53	-0.51	0.93	23.31
1936	1.28	7.22	3.52	-0.26	1.23	19.48	3.42	4.01	9.30	1.90	2.78	0.64	54.52
1937	3.08	0.59	4.21	3.24	-1.23	2.78	6.73	-0.36	6.01	9.02	8.04	3.73	45.84
1938	-0.80	-0.72	-1.03	-3.75	-1.16	1.31	4.55	-1.34	5.42	0.77	0.57	-1.80	2.02
1939	-1.54	-3.55	-2.96	-0.59	-0.36	1.34	8.02	13.5	10.28	9.66	1.16	1.36	36.31
1940	1.21	2.39	4.63	-1.18	-2.31	5.16	0.93	7.79	18.71	0.44	-1.31	2.83	39.29
1941	7.25	8.09	2.47	7.07	0.90	2.83	16.39	3.88	12.15	8.12	3.62	3.26	76.03
1942	3.60	4.91	9.89	3.03	1.28	17.24	2.62	0.9	6.81	-3.03	-1.31	1.23	47.17
1943	-0.75	-3.34	-0.03	-2.36	-3.42	-0.41	5.86	3.96	5.94	5.63	2.70	-0.95	12.83
1944	0.62	-1.36	-1.67	-1.08	-1.98	-3.13	1.34	4.75	1.46	5.68	0.03	0.10	4.76
1945	2.26	-1.23	-3.73	-2.80	-3.44	2.42	9.84	6.48	26.18	13.57	3.13	3.24	55.92

1946	2.08	-1.18	2.80	-6.06	2.67	3.73	4.50	2.36	6.14	-1.36	3.91	0.67	20.26
1947	-1.10	-0.41	11.15	-1.70	0.82	13.26	16.50	13.7	35.20	26.52	14.00	5.88	133.84
1948	10.10	3.91	1.00	2.06	-0.39	-2.34	3.44	7.91	32.71	27.73	9.17	4.47	99.77
1949	1.70	-1.39	-3.98	-1.21	-3.65	7.19	4.81	13.4	17.47	11.10	2.36	7.45	55.21
1950	-1.03	-1.05	-1.05	-4.37	-2.34	-2.62	0.93	2.39	0.05	11.79	-0.23	-0.75	1.72
1951	-1.08	0.67	-2.39	1.85	-0.93	1.16	6.27	5.52	2.93	34.15	3.42	0.95	52.52
1952	-0.31	5.09	-0.36	-2.83	0.08	0.95	3.26	6.71	7.48	27.01	4.50	0.67	52.25
1953	1.36	0.98	-1.16	1.18	-3.26	6.66	8.09	14.3	34.36	36.10	11.77	9.61	120.00
1954	5.68	3.08	3.19	2.78	3.44	19.32	13.16	8.61	11.74	5.76	1.62	1.36	79.74
1955	1.28	0.33	-2.62	-1.52	-2.98	8.79	4.55	2.34	1.46	-1.18	-1.82	-0.10	8.53
1956	-1.57	-0.95	-4.06	-2.31	-2.36	-1.54	-0.90	-0.18	3.29	17.55	0.75	0.15	7.87
1957	3.57	1.54	2.75	1.57	6.24	3.88	6.40	12.1	22.92	7.43	1.95	8.56	78.86
1958	17.78	4.19	11.95	7.30	3.49	2.06	6.30	5.42	4.81	1.41	-1.00	3.24	66.95
1959	0.31	-1.31	7.66	1.93	4.70	25.23	15.03	11.3	19.55	28.27	12.72	7.43	132.85
1960	2.47	8.20	5.47	8.15	1.59	9.15	10.10	18.3	43.25	29.68	8.51	2.08	146.97
1961	5.11	3.16	0.21	-2.13	1.21	-0.75	-0.90	2.67	-0.08	-2.00	-2.39	-2.49	1.62
1962	-0.18	-1.21	-0.93	-1.26	-2.21	6.89	9.12	9.35	22.10	0.41	-0.39	-2.72	38.97
1963	-1.31	1.93	-2.08	-5.83	-1.10	-0.44	-4.21	-1.82	-0.21	-2.47	-0.77	3.39	-14.92
1964	4.65	5.04	-0.18	0.08	-0.28	1.98	1.93	5.04	7.84	4.24	-1.93	-1.28	27.13
1965	-3.09	3.25	2.84	-5.02	-6.27	5.10	3.52	5.05	3.95	9.53	0.26	-0.06	19.04
1966	4.68	6.07	3.84	0.17	1.76	8.21	12.62	16.36	11.98	7.50	-2.93	-2.05	68.21
1967	-1.26	-1.22	-3.51	-5.90	-4.74	1.62	4.52	4.12	4.35	5.47	-3.96	-2.03	-2.55
1968	-2.52	-1.74	-3.89	-5.13	2.19	26.64	21.13	3.74	5.91	6.36	1.28	-2.84	51.14
1969	1.76	-1.44	12.03	-0.30	0.87	3.54	-0.30	9.86	6.86	33.76	7.00	8.82	82.45
1970	14.42	5.09	26.84	0.44	-1.86	1.57	4.23	2.45	-1.19	0.33	-4.09	-2.81	45.43
1971	-2.25	1.26	-4.25	-3.47	-2.62	-0.08	3.24	2.94	10.75	2.80	-1.66	-2.64	4.02
1972	-1.32	-2.65	-3.68	-2.42	2.01	7.09	-1.56	0.26	-4.15	-5.47	-1.03	-1.33	-14.25
1973	0.76	1.33	2.87	-0.73	-0.36	0.20	4.55	6.70	10.81	2.31	-4.63	-1.15	22.66
1974	-1.90	-3.04	-3.82	-5.46	-4.53	6.75	30.48	22.00	7.05	-3.46	-2.50	-1.53	40.04
1975	-2.62	-1.98	-4.02	-3.64	1.14	1.73	2.45	0.63	7.23	2.25	-2.14	-3.23	-2.19
1976	-2.75	0.48	-2.14	-3.35	3.24	5.87	-0.91	9.14	4.21	-3.22	-1.29	0.67	9.96
1977	3.52	0.51	0.05	-6.42	-1.87	0.05	-2.26	2.34	5.70	-4.13	3.18	5.60	6.28
1978	3.12	2.21	4.13	-4.11	0.13	1.80	8.03	15.72	2.78	1.37	-0.79	1.56	35.96
1979	15.12	1.72	-0.52	-4.55	4.85	-5.28	-4.50	0.28	33.85	8.80	2.27	0.24	52.28
1980	3.70	0.97	1.93	1.49	-1.35	-2.78	-0.02	0.07	1.92	-4.94	-2.53	-3.15	-4.69
1981	-3.43	-0.93	-3.71	-4.99	-4.47	-2.37	-1.21	4.34	3.34	-3.84	-2.59	-2.46	-22.31
1982	-1.41	0.67	2.97	-0.31	3.17	24.11	12.94	10.63	8.69	6.88	0.30	-2.61	66.03
1983	3.41	22.64	17.90	4.59	-3.51	1.45	1.61	3.73	2.80	4.17	-1.11	2.52	60.21
1984	1.46	3.11	7.76	3.31	3.34	-0.09	13.04	2.96	0.72	-4.34	-0.86	-2.36	28.05

1985	-1.48	-4.63	-2.17	-3.05	-2.99	-1.08	-0.26	0.88	12.00	2.67	-3.78	-1.42	-5.29
1986	1.17	2.20	2.17	-4.92	-2.96	5.59	6.90	7.18	1.47	0.12	-2.01	0.01	16.93
1987	4.95	2.67	3.79	0.61	-3.47	-2.29	-1.45	-3.90	1.69	4.72	18.02	2.28	27.65
1988	0.33	4.29	5.66	-1.06	-1.33	0.70	3.09	5.55	0.24	-4.64	-1.11	-3.03	8.69
1989	-1.05	-4.37	0.23	2.03	-2.04	-2.12	-0.73	0.99	3.10	4.34	-1.74	0.01	-1.35
1990	1.55	2.13	-1.71	-2.15	-2.30	0.26	6.23	7.93	-0.86	5.27	-2.40	-2.06	11.87
1991	2.89	-1.46	0.29	3.02	0.91	2.90	12.26	15.54	4.97	2.45	-1.80	-1.85	40.13
1992	-1.85	2.75	-1.75	0.13	-2.34	12.67	4.43	11.55	5.15	-0.87	-0.53	-0.86	28.49
1993	11.16	2.64	7.11	3.90	-3.40	-2.08	-3.61	-1.90	4.44	5.06	0.21	-1.05	22.50
1994	3.60	2.36	0.62	-0.30	-2.64	8.48	5.39	7.44	14.44	11.09	11.22	9.45	71.15
1995	4.63	3.65	5.40	0.86	-2.09	2.68	5.71	19.66	17.53	24.17	-0.53	-1.88	79.81
1996	5.04	-0.93	3.41	1.14	-0.21	7.41	1.24	-0.27	-2.51	1.20	-3.82	-3.16	8.54
1997	-1.55	-0.49	-4.06	1.91	3.11	4.87	1.69	12.13	4.08	-1.19	5.04	16.55	42.10
1998	17.69	23.25	24.69	-0.71	-5.09	-5.55	-0.49	7.07	8.47	-1.44	8.08	-2.01	73.97
1999	-0.66	-3.77	-4.43	-4.78	-1.52	9.85	5.81	5.53	13.11	16.79	-0.57	-1.62	33.74
2000	-1.90	0.07	-3.29	0.48	-9.42	-3.17	-0.08	-0.80	2.95	-2.33	-2.26	-3.18	-22.92
2001	-1.93	-1.64	-2.22	-3.72	-2.46	-0.40	5.37	8.40	17.62	7.41	1.95	-2.04	26.36
2002	0.03	-1.17	-4.11	-5.06	-6.35	8.27	19.92	9.64	13.65	-1.00	-0.14	11.48	45.17
2003	12.57	-0.63	1.49	0.66	1.68	7.49	3.73	18.45	18.55	1.72	-1.71	0.73	64.75
2004	0.82	3.17	-2.66	-4.25	-6.46	-1.01	-1.39	11.58	43.40	20.19	-1.98	-1.35	60.07
2005	-0.22	-0.52	9.52	2.04	-1.46	26.29	21.64	5.52	4.27	15.51	14.51	-0.01	97.08

Table 7-4

3-Month Window Running Sum Lake Okeechobee Net Inflow Data (Equivalent Lake Depth, in inches: Volume-depth conversion based on average Lake surface area of 467,000 acres)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1913	11.31	13.88	2.11	-3.70	-6.17	1.69	5.70	-1.54	-1.67	-3.01	0.94	-2.40
1914	-3.29	-1.69	1.47	-1.31	-1.72	-4.54	12.21	14.98	19.06	4.91	3.57	0.90
1915	0.54	-0.95	2.44	6.62	13.31	16.52	19.12	16.96	14.21	8.84	5.60	0.08
1916	-3.24	-6.61	-5.51	-0.49	9.25	11.36	11.07	5.06	7.42	4.93	-1.37	-6.71
1917	-8.46	-8.82	-10.28	-8.40	0.47	9.51	10.79	6.60	-4.71	-9.31	-7.49	0.15
1918	4.50	2.35	0.08	1.08	4.29	8.79	10.10	7.12	0.62	-3.90	-2.05	-0.10
1919	-1.29	-0.34	3.95	9.66	13.36	15.11	15.37	11.13	7.87	4.47	4.91	2.85
1920	3.11	0.64	1.67	5.11	9.94	12.66	10.15	11.02	8.22	5.42	0.03	-3.18
1921	-3.65	-4.04	-0.80	1.39	0.08	-3.57	-6.01	-2.64	3.14	6.60	4.26	-4.89
1922	-8.59	-10.90	-2.57	0.93	8.71	13.67	39.62	50.00	43.96	18.47	3.34	3.47
1923	-4.13	-8.63	-8.25	3.62	13.26	15.94	15.17	5.79	-3.82	-8.86	-4.21	0.90
1924	-2.80	-5.60	-11.46	-7.40	-0.08	2.77	10.48	30.29	43.68	42.80	25.43	21.09
1925	16.24	12.08	6.60	7.42	9.19	18.01	16.01	14.24	5.78	10.76	17.62	20.84
1926	15.34	9.66	5.24	11.87	18.17	26.49	38.00	38.33	35.87	22.31	10.59	5.75
1927	-5.05	-9.28	-8.97	-3.21	-0.18	-1.77	0.00	2.13	-2.14	-3.22	-5.30	-2.01
1928	-7.02	-7.87	-6.89	-0.93	17.44	48.02	69.92	61.78	35.57	12.72	5.88	0.46
1929	1.83	-0.40	-0.89	-1.97	4.22	8.10	25.18	37.05	38.98	22.98	9.18	9.38
1930	8.58	9.82	13.32	61.65	74.65	73.69	37.56	31.93	26.85	18.48	12.26	13.34
1931	16.01	17.27	15.01	1.88	-6.55	-4.47	9.05	12.91	7.25	-2.24	-3.81	-1.49
1932	-2.31	-5.62	-5.39	3.66	5.66	17.89	15.73	15.76	10.67	3.52	4.16	-6.55
1933	-2.95	0.62	2.88	3.40	2.73	14.37	33.71	45.97	40.93	20.07	6.19	2.52
1934	5.71	4.97	6.10	13.03	29.27	40.80	42.94	31.99	19.48	6.42	0.61	-1.65
1935	-5.24	-0.92	-2.77	3.62	-0.05	4.93	15.98	24.48	21.61	8.95	1.70	9.43
1936	12.02	10.48	4.49	20.45	24.13	26.91	16.73	15.21	13.98	5.32	6.50	4.31
1937	7.88	8.04	6.22	4.79	8.28	9.15	12.38	14.67	23.07	20.79	10.97	2.21
1938	-2.55	-5.50	-5.94	-3.60	4.70	4.52	8.63	4.85	6.76	-0.46	-2.77	-6.89
1939	-8.05	-7.10	-3.91	0.39	9.00	22.85	31.79	33.43	21.10	12.18	3.73	4.96
1940	8.23	5.84	1.14	1.67	3.78	13.88	27.43	26.94	17.84	1.96	8.77	18.17
1941	17.81	17.63	10.44	10.80	20.12	23.10	32.42	24.15	23.89	15.00	10.48	11.77
1942	18.40	17.83	14.20	21.55	21.14	20.76	10.33	4.68	2.47	-3.11	-0.83	-2.86
1943	-4.12	-5.73	-5.81	-6.19	2.03	9.41	15.76	15.53	14.27	7.38	2.37	-1.69
1944	-2.41	-4.11	-4.73	-6.19	-3.77	2.96	7.55	11.89	7.17	5.81	2.39	1.13
1945	-2.70	-7.76	-9.97	-3.82	8.82	18.74	42.50	46.23	42.88	19.94	8.45	4.14

1946	3.70	-4.44	-0.59	0.34	10.90	10.59	13.00	7.14	8.69	3.22	3.48	-0.84
1947	9.64	9.04	10.27	12.38	30.58	43.48	65.42	75.44	75.72	46.40	29.98	19.89
1948	15.01	6.97	2.67	-0.67	0.71	9.01	44.06	68.35	69.61	41.37	15.34	4.78
1949	-3.67	-6.58	-8.84	2.33	8.35	25.36	35.64	41.93	30.93	20.91	8.78	5.37
1950	-3.13	-6.47	-7.76	-9.33	-4.03	0.70	3.37	14.23	11.61	10.81	-2.06	-1.16
1951	-2.80	0.13	-1.47	2.08	6.50	12.95	14.72	42.60	40.50	38.52	4.06	5.73
1952	4.42	1.90	-3.11	-1.80	4.29	10.92	17.45	41.20	38.99	32.18	6.53	3.01
1953	1.18	1.00	-3.24	4.58	11.49	29.06	56.76	84.77	82.23	57.48	27.06	18.37
1954	11.95	9.05	9.41	25.54	35.92	41.09	33.51	26.11	19.12	8.74	4.26	2.97
1955	-1.01	-3.81	-7.12	4.29	10.36	15.68	8.35	2.62	-1.54	-3.10	-3.49	-2.62
1956	-6.58	-7.32	-8.73	-6.21	-4.80	-2.62	2.21	20.66	21.59	18.45	4.47	5.26
1957	7.86	5.86	10.56	11.69	16.52	22.33	41.37	42.40	32.30	17.94	28.29	30.53
1958	33.92	23.44	22.74	12.85	11.85	13.78	16.53	11.64	5.22	3.65	2.55	2.24
1959	6.66	8.28	14.29	31.86	44.96	51.59	45.91	59.15	60.54	48.42	22.62	18.10
1960	16.14	21.82	15.21	18.89	20.84	37.57	71.67	91.25	81.44	40.27	15.70	10.35
1961	8.48	1.24	-0.71	-1.67	-0.44	1.02	1.69	0.59	-4.47	-6.88	-5.06	-3.88
1962	-2.32	-3.40	-4.40	3.42	13.80	25.36	40.57	31.86	22.12	-2.70	-4.42	-2.10
1963	-1.46	-5.98	-9.01	-7.37	-5.75	-6.47	-6.24	-4.50	-3.45	0.15	7.27	13.08
1964	9.51	4.94	-0.38	1.78	3.63	8.95	14.81	17.12	10.15	1.03	-6.30	-1.13
1965	2.99	1.06	-8.46	-6.20	2.35	13.67	12.52	18.53	13.74	9.73	4.89	10.69
1966	14.59	10.08	5.77	10.14	22.59	37.19	40.95	35.84	16.55	2.52	-6.24	-4.53
1967	-5.99	-10.63	-14.15	-9.02	1.39	10.26	12.99	13.94	5.86	-0.53	-8.52	-6.29
1968	-8.15	-10.76	-6.84	23.70	49.96	51.52	30.79	16.01	13.55	4.81	0.21	-2.51
1969	12.35	10.28	12.59	4.11	4.11	13.10	16.42	50.48	47.62	49.58	30.24	28.33
1970	46.35	32.38	25.43	0.16	3.94	8.25	5.49	1.59	-4.95	-6.57	-9.15	-3.81
1971	-5.24	-6.46	-10.34	-6.16	0.55	6.10	16.93	16.49	11.89	-1.50	-5.63	-6.62
1972	-7.65	-8.75	-4.08	6.69	7.54	5.78	-5.46	-9.36	-10.65	-7.82	-1.59	0.77
1973	4.96	3.47	1.78	-0.89	4.39	11.45	22.07	19.82	8.49	-3.48	-7.69	-6.09
1974	-8.77	-12.33	-13.82	-3.24	32.70	59.23	59.52	25.59	1.09	-7.48	-6.64	-6.12
1975	-8.61	-9.64	-6.52	-0.77	5.32	4.81	10.31	10.12	7.34	-3.12	-8.12	-5.50
1976	-4.41	-5.01	-2.25	5.76	8.20	14.10	12.44	10.14	-0.30	-3.83	2.90	4.70
1977	4.08	-5.86	-8.23	-8.24	-4.08	0.13	5.78	3.91	4.75	4.65	11.90	10.93
1978	9.46	2.23	0.15	-2.18	9.97	25.56	26.53	19.87	3.36	2.14	15.90	18.41
1979	16.33	-3.34	-0.21	-4.98	-4.94	-9.50	29.63	42.92	44.91	11.30	6.21	4.90
1980	6.60	4.39	2.07	-2.64	-4.16	-2.74	1.97	-2.95	-5.55	-10.61	-9.11	-7.51
1981	-8.07	-9.62	-13.16	-11.82	-8.05	0.76	6.47	3.84	-3.09	-8.89	-6.45	-3.19
1982	2.23	3.33	5.83	26.96	40.21	47.67	32.26	26.20	15.87	4.57	1.11	23.45
1983	43.95	45.13	18.98	2.53	-0.45	6.79	8.14	10.70	5.86	5.59	2.88	7.10
1984	12.33	14.17	14.40	6.55	16.29	15.91	16.73	-0.65	-4.48	-7.56	-4.70	-8.47

1985	-8.27	-9.85	-8.21	-7.12	-4.33	-0.46	12.63	15.56	10.90	-2.52	-4.03	1.95
1986	5.54	-0.55	-5.71	-2.28	9.54	19.68	15.55	8.77	-0.42	-1.87	2.95	7.64
1987	11.42	7.07	0.94	-5.15	-7.20	-7.63	-3.65	2.52	24.43	25.03	20.64	6.91
1988	10.28	8.89	3.27	-1.69	2.46	9.33	8.87	1.15	-5.51	-8.78	-5.19	-8.45
1989	-5.19	-2.11	0.22	-2.13	-4.89	-1.86	3.36	8.43	5.70	2.61	-0.18	3.69
1990	1.96	-1.73	-6.16	-4.19	4.19	14.42	13.29	12.33	2.00	0.80	-1.57	-0.63
1991	1.72	1.85	4.22	6.83	16.07	30.70	32.77	22.96	5.62	-1.20	-5.50	-0.95
1992	-0.85	1.13	-3.95	10.47	14.77	28.65	21.12	15.82	3.75	-2.26	9.77	12.95
1993	20.91	13.66	7.62	-1.57	-9.09	-7.59	-1.07	7.61	9.71	4.22	2.76	4.91
1994	6.57	2.67	-2.33	5.54	11.23	21.32	27.28	32.97	36.75	31.76	25.31	17.73
1995	13.68	9.91	4.18	1.46	6.30	28.06	42.91	61.37	41.18	21.76	2.63	2.23
1996	7.53	3.62	4.33	8.33	8.44	8.38	-1.53	-1.58	-5.13	-5.79	-8.53	-5.20
1997	-6.09	-2.63	0.97	9.89	9.67	18.69	17.91	15.02	7.93	20.39	39.27	57.49
1998	65.63	47.23	18.89	-11.35	-11.13	1.02	15.05	14.10	15.12	4.64	5.41	-6.44
1999	-8.86	-12.98	-10.73	3.56	14.14	21.19	24.45	35.43	29.33	14.59	-4.09	-3.45
2000	-5.13	-2.75	-12.23	-12.10	-12.66	-4.04	2.07	-0.18	-1.64	-7.77	-7.37	-6.75
2001	-5.78	-7.57	-8.39	-6.58	2.51	13.38	31.40	33.43	26.98	7.33	-0.05	-3.17
2002	-5.24	-10.34	-15.51	-3.13	21.85	37.84	43.22	22.29	12.50	10.33	23.91	23.43
2003	13.44	1.52	3.83	9.83	12.90	29.67	40.74	38.72	18.56	0.74	-0.15	4.73
2004	1.34	-3.73	-13.37	-11.71	-8.85	9.19	53.59	75.17	61.61	16.86	-3.55	-2.09
2005	8.78	11.04	10.10	26.87	46.47	53.44	31.43	25.29	34.28	30.00	15.85	4.99

APPENDIX I

Appendix I

Methods Used to Produce the Lake Okeechobee Net Inflow Outlook

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Seasonal Climate Outlook

The 2008 Lake Okeechobee Regulation Schedule (2008 LORS) seasonal operational outlook is based on the prediction of total six-month net inflow into Lake Okeechobee, which will be updated each month. These classifications are for the expected net gain in storage in the lake after taking into account ET losses during the six-month period. Utilizing climate outlooks together with the Lake Okeechobee historical inflows for the appropriate months allows the development of the Lake Okeechobee net inflow outlooks. The term "seasonal" is not applied in the most typical sense in that it actually refers to a six-month moving window that is updated each month of the year and does not pertain to a particular season of the year. The methodologies for the Seasonal and Multi-seasonal Climate Outlooks are described below.

The current season is defined as the time window starting with the current month and extending six months into the future. Therefore, the seasonal climate outlook always comprises 6 months. The primary variable is the quantitative estimate of net inflow into Lake Okeechobee for the current season. Historical net inflows to Lake Okeechobee are used in the process of producing outlooks for the Lake. The monthly data is presented in Table 7-8, which follows the Water Control Plan (WCP). The 3-month window running sum values for Lake Okeechobee net inflow are presented in Table 7-9, also following the WCP. A working definition of the Lake Okeechobee net inflow (LONIN) is given by

$$LONIN = rf - et + inflow \qquad (1)$$

where rf is the rainfall volume over the Lake, et is evapotranspiration volume from the lake marsh and surface areas, and inflow represents the total structural inflow volume into the lake.

To produce the Lake Okeechobee net inflow outlook (LONINO) for the current season, historical data (or a summary of it) is transformed by various

methods described below so that it reproduces the official Climate Prediction Center climate outlooks. For instance, the outlook information is posted monthly by NOAA's Climate Prediction Center (CPC):

http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/seasonal_forecast.html.

The CPC produces climate outlook windows for a one-month window for the next month and 13 three-month overlapping windows going into the future, in one-month increments. The climate outlooks are presented in maps and for each time period they give the probability of temperature and rainfall being above normal, normal and below normal.

The methods used to produce the Lake Okeechobee net inflow outlook include Croley's method (1996), the SFWMD empirical method, sub sampling of historical years and possibly some other experimental forecast methods.

As much as possible, all of the above methods should be used any time 2008 LORS flowcharts - Parts C and D - requires a seasonal outlook in order to verify results and detect possible outliers. Also, under certain conditions, Croley's method may not yield a feasible solution, in which case, it will be necessary to revert to the other methods. Additionally, as new and improved forecast methods are developed, tested and published, they should be incorporated into the operational methodology for Lake Okeechobee.

Croley's method (1996) uses historical monthly rainfall for the tributary basins into Lake Okeechobee (1914-2005), historical Lake Okeechobee net inflows (1914-2005) (Table 7-8), and the CPC outlook probabilities for rainfall. The basic idea is to obtain monthly weights, denoted $w_{i,j}$, $i=1,..,n$, $j=1,..,12$, where n is the available sample size in years, such that when applied to the historical rainfall data, the CPC outlook probabilities for rainfall are reproduced. Once weight values are obtained, the forecast Lake

Okeechobee net inflow for each month X_j, j=1,…,12, is:

$$X_j = \sum_{i=1}^{n} w_{i,j}\ x_{i,j} \qquad (2)$$

where $x_{i,j}$ represents the historical monthly Lake Okeechobee net inflow for month j, year i. The methodology to obtain the weights is presented by Croley (1996).

The seasonal Lake Okeechobee net inflow outlook X_S is then formed as:

$$X_S = \sum_{i=j_0}^{j_0+5} X_j \qquad (3)$$

where j_0 denotes the current month (start of the current season). The methodology and an application of Croley's method to the operational hydrology of south Florida are described by Cadavid et al. (1999). A copy of this publication is provided in Appendix J. Note that Croley's method derives the weights based on rainfall data, but they are applied to Lake Okeechobee net inflow data. The input data to Croley's and other methods presented here will be updated as soon as it becomes available.

The SFWMD empirical method was developed by the SFWMD as an alternate to Croley's method, to utilize the information provided by the CPC when the above method yields no feasible solution. For the seasonal climate outlook (6-month window), the empirical method uses an equation of the form:

$$X_S = a_0^{(6)} + a_1^{(6)}\ Y_1^{(6)} + a_2^{(6)}\ Y_2^{(6)} + a_3^{(6)}\ Y_3^{(6)} \qquad (4)$$

where X_S is the seasonal Lake Okeechobee net inflow outlook value expressed in <u>inches</u> of equivalent lake depth and the a_i are empirical coefficients with the values given below

$$a_0^{(6)} = -0.1845$$
$$a_1^{(6)} = 0.5929$$
$$a_2^{(6)} = 0.2638$$
(5)
$$a_3^{(6)} = 0.2388$$

and $Y_1^{(6)}$, $Y_2^{(6)}$ and $Y_3^{(6)}$ are the expected Lake Okeechobee net inflows for windows of different duration, conditional on the CPC forecast, as specified below:

$$Y_1^{(6)} = \hat{E}_{X/CPC}\left[X_{j_0}\right]$$
(6)

where as before, j_0 denotes the first month in the current season,

$$Y_2^{(6)} = \sum_{k=j_0}^{j_0+3} f^{(6)}{}_{k-j_0+1}\, \hat{E}_{Z/CPC}\left[Z_k\right]$$
(7)

$$Y_3^{(6)} = \hat{E}_{Z/CPC}\left[Z_{j_0+4}\right]$$
(8)

Z_k represents the Lake Okeechobee net inflow for the three-month window starting at month k and $E[.]_{Z/CPC}$ represents statistical expectation conditional on the CPC forecast. Historical values for Z_k are given in Table 7-9, which follows the WCP text.

All the independent variables in equation (4) must be expressed in inches of equivalent depth over the lake. Depth-volume conversions for the lake are based on an average surface area of 467000 acres. Also, the coefficients $a_i^{(6)}$ in equation (4) were derived using linear regression analysis. The superscript (6) indicates that variables are applicable to the 6-month duration window.

If the summation limits and/or indices in equations (3) and (7) take values greater than 12, new limits and/or indices are obtained by subtracting 12 from the old values.

The windows associated with $Y_1^{(6)}$, $Y_2^{(6)}$ and $Y_3^{(6)}$ have durations of 1, 6 and 3 months, respectively. $Y_1^{(6)}$ contains 1 1-month window, $Y_2^{(6)}$ contains 4 3-month windows and $Y_3^{(6)}$ contains 1 3-month window.

The factors $f_k^{(6)}$ represent heuristic factors applied to the three-month windows and they do not depend on the current month, but they are unique for the six month window:

$$f_1^{(6)} = 11/6$$
$$f_2^{(6)} = 7/6$$
$$f_3^{(6)} = 7/6 \qquad (9)$$
$$f_4^{(6)} = 11/6$$

The conditional expected values in equations (6) to (8) are obtained by combining the CPC probabilities with mid point values for the three terciles derived for the historical Lake Okeechobee net inflow data, for the period 1914-1998 and for the corresponding windows. The tercile midpoints were derived for the one- and three-month windows by ranking the historical data, estimating the 33% and 67% quantiles, and then finding by inspection the mid point values for the three probability intervals 0-33% (Lower), 33%-67% (Middle) and 67%-100% (Upper), for each sample. Tables I-1 and I-2 present the estimated tercile midpoints.

The term in equation (6) becomes:

$$\hat{E}_{X/CPC}\left[X_j\right] = X_{L,j}\; P(BN)_j + X_{M,j}\; P(N)_j + X_{U,j}\; P(AN)_j \qquad (10)$$

Similarly, for the three month windows

$$\hat{E}_{Z/CPC}\left[Z_k\right] = Z_{L,k}\;\; P(BN)_k \;\; + Z_{M,k}\;\; P(N)_k \;\; + Z_{U,k}\;\; P(AN)_k \qquad (11)$$

where $X_{L,j}$, $X_{M,j}$ and $X_{U,j}$ are the tercile mid points for the Lake Okeechobee net inflow for month j and $Z_{L,k}$, $Z_{M,k}$ and $Z_{U,k}$ are the tercile mid points for the Lake Okeechobee net inflow for the 3-month window starting in month k (Table I-1 and Table I-2). In the same way, $P(BN)_j$, $P(N)_j$ and $P(AN)_j$ are the CPC

outlook probabilities for month j and $P(BN)_k$, $P(N)_k$ and $P(AN)_k$ are the same probabilities for the three-month windows.

Table I-1. Tercile mid points for one month Lake Okeechobee net inflows[inches over surface area],

acres).

Month	Lower Tercile X_L	Middle Tercile X_M	Upper Tercile X_U
January	-1.5	0.8	4.7
February	-1.6	0.6	4.1
March	-3.7	0.2	4.6
April	-4.3	-0.7	2.9
May	-3.4	-0.8	2.3
June	-1.1	2.2	8.3
July	-0.7	4.4	10.4
August	0.7	5.5	11.9
September	1.6	6.1	18.5
October	-1.3	4.2	14.8
November	-2.2	0.3	4.9
December	-2.1	0.2	3.7

Table I-2. Tercile mid points for 3-months Lake Okeechobee net inflows [inches over surface area], based on period 1914-1998 (Depth-volume conversion

acres).

Month	Lower Tercile Z_L	Middle Tercile Z_M	Upper Tercile Z_U
January	-5.2	2.0	13.2
February	-7.5	0.1	10.0
March	-8.4	-0.6	9.1
April	-6.2	1.4	10.4
May	-4.0	6.5	18.0
June	0.8	13.4	29.0
July	5.9	16.0	40.4
August	4.1	15.8	41.8
September	-0.4	11.9	38.6
October	-3.2	4.9	20.9
November	-5.2	2.9	12.2
December	-4.4	2.0	12.7

Table I-3 defines the class limits for classification of the Lake Okeechobee Seasonal outlook.

Table I-3. Classification of Lake Okeechobee Net Inflow Seasonal Outlooks.

Lake Net Inflow Prediction (million acre-feet)	Equivalent Depth[1] (feet)	Lake Net Inflow Outlook
>0.93	**>2.0**	**Very Wet**
0.71 to 0.93	**1.51 to 2.0**	**Wet**
0.35 to 0.70	**0.75 to 1.5**	**Normal**
< 0.35	**< 0.75**	**Dry**

Multi-seasonal Climate Outlook

1 Volume-depth conversion based on average lake surface area of 467000 acres.

The onset of hydrologic drought in Florida is often initiated with below normal wet season (May - October) rainfall which leads to lower availability of water supply for the upcoming dry season months (November-April). This is especially crucial if a La Nina condition develops in the equatorial Pacific Ocean during the following winter months. On the other hand, above normal wet season rainfall often leads to the need for discharges from Lake Okeechobee during the same dry season. This latter event is especially crucial if an El Nino condition develops in the tropical Pacific during the

the design of the 2008 LORS flowcharts - Parts C and D - included a multi-seasonal hydrologic outlook as one of the key decision criterion. This criterion is based on the expected inflow during the remainder of the current hydrologic (wet or dry) season and the entire six-months of the next season. The multi-seasonal hydrologic outlook is therefore defined as either: (1) the remainder of the wet season and the upcoming dry season, or (2) the remainder of the dry season and the upcoming wet season. The last 1 to 2 months of a particular season are considered as transition months. During the transition from 'dry season' to 'wet season', during the months of March and April, if the multi-seasonal climate outlooks indicate an increased likelihood of below normal rainfall for the next two consecutive seasons (May to April), then the multi-seasonal outlook should be formed using the climate forecasts for the on-coming May to April period. Likewise during the transition from 'wet season' to 'dry season', during the months of September and October, if the multi-seasonal climate outlooks indicate an increased likelihood of above normal rainfall for the upcoming two consecutive seasons (November to October), then the multi-seasonal outlook should be formed using the climate forecasts for the on-coming November to October period. The multi-seasonal forecasts for May through April becomes available by mid-March,

through October becomes available by mid-September. This is the earliest date that the transition should be made.

The multi-seasonal outlook is the quantitative

duration of the multi-seasonal window varies between 7 and 12 months.

The production of the Lake Okeechobee net inflow outlook for the multi-seasonal window utilizes the same materials and procedures as in the seasonal outlook: CPC outlook probabilities for rainfall in south Florida, historical Lake Okeechobee net inflow data for the period 1914-1998, and summary of the historical Lake Okeechobee net inflow data in the form of the tercile midpoints presented in Tables I-1 and I-2. The methods used to compute the multi-seasonal outlook are the same, with the variations defined below.

Croley's method (1996): This method is applied in a similar fashion, with the exception that additional months are used to compute the multi-seasonal Lake Okeechobee net inflow. The multi-seasonal forecast, X_{MS}, is then formed as:

$$X_{MS} = \sum_{i=j_0}^{j_0+n-1} Xi \qquad 7 \le n \le 12 \quad (12)$$

where j_0 denotes the first month in the multi-seasonal window (current month) and n denotes the duration of the multi-seasonal window.

SFWMD empirical method: In this case, the methodology presented for a window of duration 6 months is generalized to a duration between 7 and 12 ($7 \le n \le 12$) months. To produce the multi-seasonal Lake Okeechobee net inflow outlook, the empirical method uses an equation of the form:

$$X_{MS} = a_0^{(n)} + a_1^{(n)}\ Y_1^{(n)} + a_2^{(n)}\ Y_2^{(n)} + a_3^{(n)}\ Y_3^{(n)} \quad (13)$$

where X_{MS} is the multi-seasonal Lake Okeechobee net inflow outlook value in <u>inches</u> and the $a_i^{(n)}$ are empirical coefficients which depend on the duration of the window. Values for the empirical

coefficients were derived using regression analysis and they are listed in Table I-4. For generalization purposes, results presented in this section will include the seasonal outlook case.

Table I-4. Regression coefficients to estimate Seasonal and Multi-seasonal Lake Okeechobee Net Inflow Outlook Values.

Window Duration (n)	$a_0^{(n)}$	$a_1^{(n)}$	$a_2^{(n)}$	$a_3^{(n)}$
6	-0.1845	0.5929	0.2638	0.2388
7	-0.1743	0.5567	0.2784	0.2175
8	-0.1060	0.5086	0.2888	0.1975
9	-0.0592	0.4787	0.2959	0.1834
10	-0.0270	0.4626	0.3012	0.1695
11	0.0517	0.4261	0.3058	0.1555
12	0.1367	0.3966	0.3091	0.1436

As before, $Y_1^{(n)}$, $Y_2^{(n)}$ and $Y_3^{(n)}$ are the expected Lake Okeechobee net inflows for windows of different duration, conditional on the CPC forecast, as specified below:

$$Y_1^{(n)} = \hat{E}_{X/CPC}\left[X_{j_0}\right] \qquad (14)$$

where now j_0 denotes the first month in the current multi-seasonal window,

$$Y_2^{(n)} = \sum_{k=j_0}^{j_0+w-1} f^{(n)}{}_{k-j_0+1}\, \hat{E}_{Z/CPC}\left[Z_k\right] \qquad (15)$$

with

$$w = n - 2 \qquad (16)$$

and w represents the number of complete 3-month windows falling inside the multi-seasonal window. Finally,

$$Y_3^{(n)} = \hat{E}_{Z/CPC}\left[Z_{j_0+w}\right]$$
(17)

As stated before, Z_k represents the Lake Okeechobee net inflow for the three-month window starting at month k and $E[.]_{Z/CPC}$ represents statistical expectation conditional on the CPC forecast. Historical data for Z_k is presented in Table 7-9, which follows the WCP.

All the independent variables in equation (13) must be expressed in inches of equivalent depth over the lake. Depth-volume conversions for the lake are based on an average surface area of 467000 acres. Also, the coefficients $a_i^{(n)}$ in equation (13) were derived using linear regression analysis. The superscript (n) indicates that variables are applicable to a specific n-month duration window.

If the summation limits and/or indices in equations (3) and (7) take values greater than 12, new limits and/or indices are obtained by subtracting 12 from the old values.

The windows associated with $Y_1^{(n)}$, $Y_2^{(n)}$ and $Y_3^{(n)}$ have durations of 1, n and 3 months, respectively. $Y_1^{(n)}$ contains 1 1-month window, $Y_2^{(n)}$ contains w 3-month windows and $Y_3^{(n)}$ contains 1 3-month window.

The factors $f_k^{(n)}$ represent heuristic factors applied to the three-month windows. They do not depend on the current month, but they are unique for each duration. Values for these factors are given in Table I-5.

Finally, the conditional expected values in equations (14), (15) and (17) are obtained using equations (10) and (11).

Table I-5. Factors used in the estimation of Seasonal and Multi-seasonal Lake Okeechobee Net Inflow outlooks.

Duration (n)	6	7	8	9	10	11	12
$f_1^{(n)}$	11/6	11/6	11/6	11/6	11/6	11/6	11/6
$f_2^{(n)}$	7/6	7/6	7/6	7/6	7/6	7/6	7/6

$f_3^{(n)}$	7/6	6/6	6/6	6/6	6/6	6/6	6/6
$f_4^{(n)}$	11/6	7/6	6/6	6/6	6/6	6/6	6/6
$f_5^{(n)}$		11/6	7/6	6/6	6/6	6/6	6/6
$f_6^{(n)}$			11/6	7/6	6/6	6/6	6/6
$f_7^{(n)}$				11/6	7/6	6/6	6/6
$f_8^{(n)}$					11/6	7/6	6/6
$f_9^{(n)}$						11/6	7/6
$f_{10}^{(n)}$							11/6

Table I-6 defines the class limits for classification of the Lake Okeechobee Multi-Seasonal outlook.

Table I-6 Classification of Lake Okeechobee Net Inflows Multi-Seasonal Outlook.

Lake Inflow Prediction (million acre-feet)	Equivalent Depth[2] (feet)	Lake Inflow Outlook
>2.0	>4.3	Very Wet
1.18 to 2.0	2.51 to 4.3	Wet
0.5 to 1.17	1.1 to 2.5	Normal
< 0.5	< 1.1	Dry

2 Volume-depth conversion based on average lake surface area of 467000 acres.

Sub Sampling Methodology

The last method is derived by sub sampling from the Lake net inflow historical sample, according to different global indicators which have been found to influence south Florida climate. These indicators, also known as teleconnections (Obeysekera et al, 2000), include the El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) and the Atlantic Multi-decadal Oscillation (AMO). They reflect temperature anomalies (above, below or normal conditions) for different regions in the earth's oceans. For instance, based on research by Enfield et al. (2001) and by Mestas-Nuñez et al. (2003), the currently preferred method to produce LONINO values extracts from the Lake net inflow historical sample monthly values which fall on the same category as the current and forecast indicators for AMO and ENSO combined. As of the end of 2007, AMO was in the positive phase, while ENSO was under negative (La Niña) conditions. The outlooks are computed as the expected values of monthly volumes, considering only those months for which the selected indicators apply.

Access Climate Indices

There are several representations and sources of the key climate indicators mentioned above. The source for determining the phase of ENSO is Climate Prediction Center (CPC). Nino 3 is the official index to determine the phase of ENSO for Lake Okechobee operations. This index is the sea surface temperature anomalies in a particular region of the Equatorial Pacific Ocean. When the index (SSTA) persists below -0.5 centigrade for several months, La Nina conditions are in place; when sea surface temperature anomalies persist at greater than 0.5 centigrade, El Nino conditions are in place. The current weekly value of the Nino 3 index may be found at the following location:
http://www.cpc.ncep.noaa.gov/data/indices/wksst.for
The CPC also produces a weekly expert assessment of the current state of ENSO. This report may be found at the following link:
http://www.cpc.ncep.noaa.gov/products/expert_assessment/
Nino 3 data was also used during the modeling and tool preparation for the 2008 LORS , although

monthly values were used in this case. Also, threshold values of 0.4 and -0.4 were used to declare El Nino or la Nina conditions, respectively. The Nino 3 Index monthly data can be easily obtained from:
http://www.cpc.ncep.noaa.gov/data/indices/sstoi.indices
The PDO and AMO are indices that are calculated each month. However, the state of each phenomenon is estimated by averaging the monthly computed index over several years. The PDO generally is averaged over 5 years while the AMO is averaged over 10 years. These oscillations are only quasi-periodic so the great challenge for the climate experts is to determine when a phase shift is about to occur. The latest PDO index may be found at:
http://jisao.washington.edu/pdo/PDO.latest
The AMO information may be found at:
http://www.cdc.noaa.gov/Correlation/amon.us.long.data

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APPENDIX J

Appendix J

Operational Hydrology in South Florida Using Climate Forecast

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Operational Hydrology in South Florida Using Climate Forecast

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Cary White, Paul Trimble and Jayantha T. B. Obeysekera[1]

ABSTRACT

The South Florida Water Management District (SFWMD) uses unconditional and conditional position analysis as one of several decision tools in planning the operation of the system. The Object Oriented Routing Model (ORM), a lumped parameter hydrologic simulation model for the SFWMD system, is reinitialized to current conditions for every year in the simulation period. Model results are presented as stage time series of percentile traces for Lake Okeechobee and other impoundments in the system. Conditional position analysis is obtained when a given (dry or wet) climatic forecast is incorporated into the analysis.

INTRODUCTION

The South Florida Water Management District (SFWMD) manages the water resources of South Florida for the benefit of the region, balancing the needs of present generations with those of future generations. Equally important elements of this stewardship are the conservation and development of water supply, the protection and improvement of water quality, the mitigation of impacts from flood and drought, and the restoration and preservation of natural resources.

Drainage in South Florida, for the purpose of land reclamation, began in the middle 1800's and has evolved into an extensive and complex network of lakes, reservoirs, canals and levees, interconnected by different types of water control structures. The current system, known as the Central and South Florida (C&SF) Project, was designed and built by the U.S. Army Corps of Engineers (USACE) and the local sponsor is SFWMD. The C&SF project is multi-purpose and provides flood control and protection, water supply for municipal, industrial and agricultural uses, prevention of salt-water intrusion, environmental water supply for the Everglades and protection of natural resources. The C&SF project has made it possible for millions of people to live in central and south Florida.

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The heart of the SFWMD system (Figure 1) is Lake Okeechobee, the second largest fresh water lake located contiguously within the U.S. The Kissimmee River and Fisheating Creek provide most of Lake Okeechobee inflows. The SFWMD system includes approximately 1400 miles (2250 km) each of both levees and canals, more than 200 water control structures and 18 major pump stations. Lake Okeechobee has two outlets, the Caloosahatchee River to the west and the St. Lucie Canal to the east, which discharge through the tidal estuaries to the ocean. Four major canals (West Palm Beach, Hillsboro, North New River and Miami) convey water supply to the Lower East Coast (LEC) and flood control releases from Lake Okeechobee to the south. These canals traverse the Water Conservation Areas (WCAs) and capture excess runoff from the Everglades Agricultural Area (EAA). The 5 WCAs, WCA-1, WCA-2A, WCA-2B, WCA-3A and WCA-3B, work as shallow, above the ground impoundments. The rich soils in the EAA, located in between Lake Okeechobee and the WCAs, are used for production of sugar cane, sod and winter vegetables. Lake Okeechobee supplies water to both the EAA and the communities around the Lake (Lake Okeechobee Service Areas, LOSA). An important feature of south Florida hydrology is the continuous interaction between ground water and surface water.

The water control system of south Florida is complex, not only in its configuration, but also in its operation. It is a multi-objective system. Conflicting water needs necessitate the use of appropriate water management decision tools. The ability to look into probable future responses of the system, given the current state and future climatic forecasts, is a valuable tool to water managers. Position analysis (Hirsch, 1978) examines the future behavior of the system by estimating the risks associated with a given operational plan over a period of a few months.

The SFWMD is currently using position analysis as a decision tool in planning the future operation of the system at the monthly and seasonal level. To perform position analysis, a hydrologic simulation model is reinitialized to historical or known storage conditions on a given date, for every year in the simulation period. Processing of model results allows the evaluation of probabilities associated with different type of events. Position analysis can be applied to any variable represented in the simulation model.

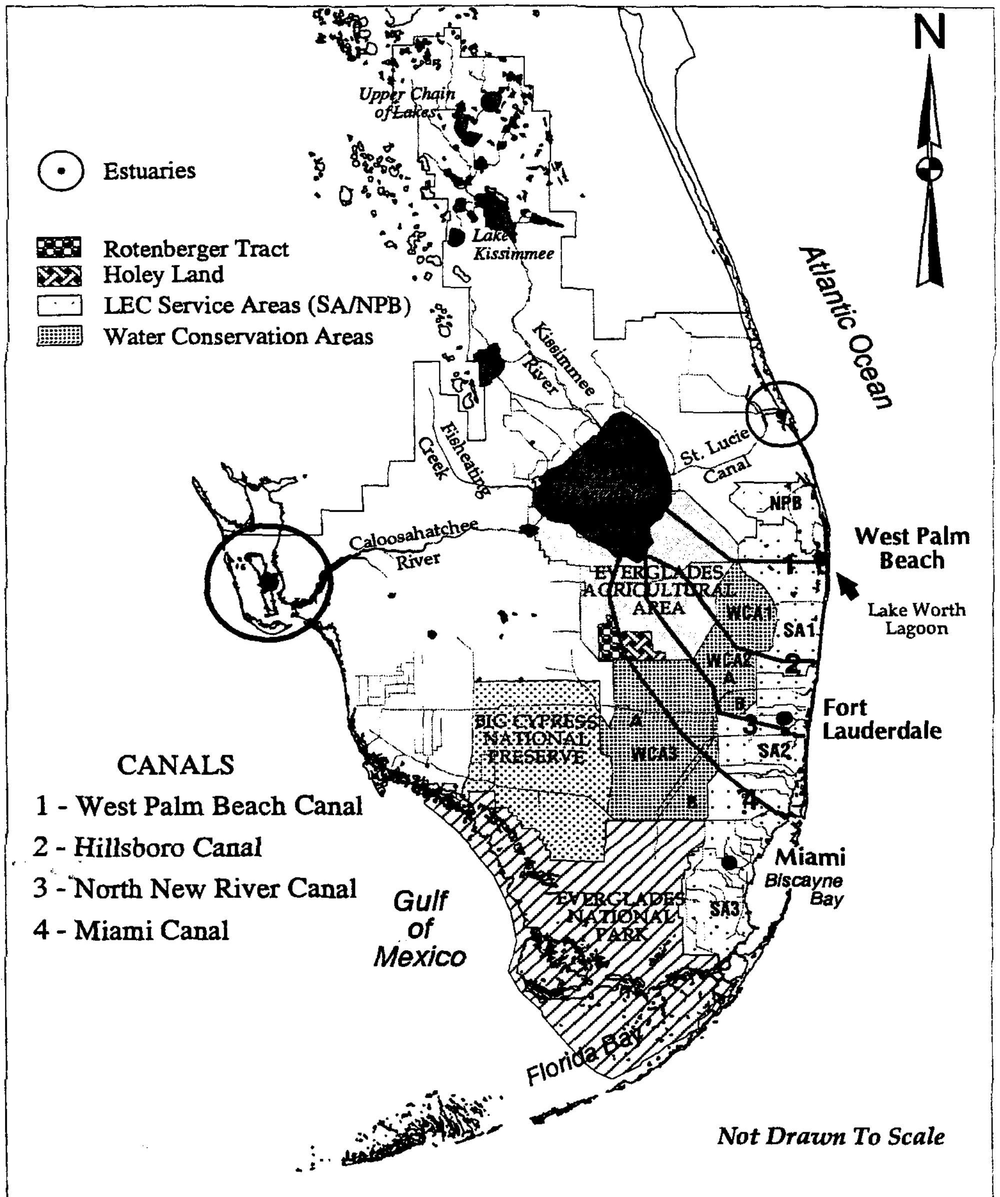

Figure 1. The current South Florida water control system.

Conditional position analysis is obtained when model results are shifted (up or down) according to a given (wet or dry) climatic forecast.

The SFWMD has extensively developed and applied the South Florida Regional Routing Model (SFRRM) (Trimble and Marban, 1989). The SFRRM, based on mass balance, conceptualizes the water control system as a series of interconnected

reservoirs and basins. The SFRRM has been re-coded and improved as the Object Oriented Routing Model (ORM).

Several reasons favored the selection of the ORM as the first hydrologic simulation model to use in operational planning by the SFWMD: 1) Extremely easy to learn and use, 2) Turn around and execution times are fast, and 3) As a lumped parameter model, re-initialization of the system is an easy task. Other models, such as the South Florida Water Management Model (SFWMD, 1999), are currently being conditioned to run in position analysis mode.

The implementation of operational planning at the SFWMD has been a joint effort with USACE, Jacksonville District, Water Management and Meteorology Section.

This paper provides a brief description of the SFRRM and the ORM. It describes the methodologies used to do position analysis and conditional position analysis. It also gives an accounting of the major advantages and shortcomings found in applying these methodologies to the south Florida water control system.

THE SFRRM AND THE ORM

Both the SFRRM and the ORM conceptualize south Florida hydrology as a linked system of "pots" or "basins". The methodology implemented in the models is a daily mass balance approach, applied to the main reservoirs and basins in the system. The SFRRM was developed as an easy to use tool to analyze the response of the system to different structural or operational modifications (Trimble, 1986; Trimble and Molina, 1991).

The SFRRM and the ORM are capable of simulating the hydrology and the management of the current system. They include Lake Okeechobee, the LOSA, the EAA, the WCAs and the LEC Service Areas. The time step for the simulations is daily. Currently, the SFWMD has the capability of running the ORM using 31 years (1965-1995) of daily historical hydro-meteorological data.

Storage in each reservoir fluctuates from day to day in response to flows in or out: overland flow, rainfall, evapotranspiration (ET), seepage, and surface water discharges through water control structures. For the simulation of reservoirs, the models use the concept of Modified Delta Storage (MDS). The simulated storage in any day (t) of the simulation is given by:

$$S(t) = S(t-1) + MDS(t) + QIN(t) - QOUT(t) - ET(t) - SPG(t) \qquad (1)$$

$$MDS(t) = \Delta S_{HIS}(t) - [QIN_{HIS}(t) - QOUT_{HIS}(t)] + ET_{HIS}(t) + SPG_{HIS}(t) \quad (2)$$

where S is the simulated storage, QIN and QOUT are simulated inflows and outflows, ET is the simulated evapotranspiration, and SPG are simulated seepage losses. The historical components, identified by the subscript HIS, are defined similarly. The daily historical storage change, ΔS_{HIS}, is obtained from recorded stages and the stage-storage relationship for the reservoir. Structure flows are obtained from historical records, while ET and seepage may be estimated as a function of historical pan evaporation and stages. Equation (1) considers only the components of the water budget that will be altered under the simulation. Rainfall is considered to change storage during the simulation exactly as it did historically and for this reason is not included in the simulated storage (eqs. (1) and (2)).

The equations are applied in two steps. First, historically recorded data is processed to compute MDS. The reservoir is returned to a pre-management condition for each daily time step. In this sense, MDS represents net inflow to the reservoir. An important feature of MDS is its ability to account for unknown or unrecorded inflows and outflows to the reservoir, through the ΔS_{HIST} term. Viewed this way, MDS is an input time series to the SFRRM or the ORM simulations. The second step is executed during the simulation. It adds MDS to the initial storage and calculates the new discharges, including ET and seepage, based on the projected storage quantities, but with new management schemes in effect. ET volume is a function of surface area inundated by water, and seepage is a function of stage in the reservoir.

Water deliveries from one region to another are made according to flood control, water supply or environmental needs. The conveyance limitations built into the models were chosen to simulate daily discharge values in such a way that historical average flows are reproduced on a monthly or seasonal basis, and not to incorporate hydraulic conditions that may exist for shorter periods of time. Most of the conveyance limitations were derived from historical data.

The ORM is the SFRRM recast as an object oriented model. Therefore, the ORM inherits most of the features of the SFRRM. In the ORM, water moves between basins through flowways, in response to the water management objectives. Each of the elements -- basins, flowways and water management objectives -- is represented by objects in the ORM.

Basins and flowways are fundamental objects that represent the conceptualized physical system of basins and their linkages. Basins are generally aligned along hydrologic basin boundaries with well-defined inflows and outflows. Internal hydrologic complexities are hidden, simplified, lumped or pre-processed so that only inter-basin transfers are simulated at the regional level. Flowways represent the physical connection between basins, e.g. structure, canal, or structure-canal combinations.

Basins typically have water supply or flood control needs that can not be adequately met through their own internal resources. Management objects are used to assess the condition of a basin and quantify the deficit or excess needs that must be resolved at the regional level. Transfer objects provide the mechanism for exchanging water between basins. These objects manage a collection of supplier or flood outlet conduits that move water between a "served" basin and one or more affected basins. A conduit simulates the actual operation of a flowway. Operational controls for a flowway are contained in policy objects. Policies are the expression of management constraints that may set or limit the quantity of water moved through the flowway. For example, water supply releases through a flowway are stopped if stages in the upstream basin drop below an environmentally sensitive level. If no policies are specified, a conduit will direct the flowway to move enough water to satisfy the water supply or flood control need, subject to the conveyance capacity of the flowway.

POSITION ANALYSIS

Position analysis is a special form of risk analysis. Its purpose is the evaluation of water resources systems and the risks associated with operational decisions (Hirsch, 1978; Smith et al., 1992). This evaluation is accomplished by estimating the probability distribution function of variables related to the water resources system, conditional on the current or a given state of the system. The terms position analysis and unconditional position analysis are used interchangeably in this article.

Assume that water managers require information on the future behavior of the system, conditional on the state of the system on June 1, 1999. Then, position analysis is required. The ORM is run for the period of simulation and the storage at the beginning of June 1, for every year and every reservoir in the system, is reset to the value corresponding to June 1, 1999. A total of 30 realizations of system response to different climatic inputs are obtained, each equally likely to take place in the future. Each realization or scenario starts on June 1 of a given year and ends on May 31 of the next year. Complete realizations are available starting in June 1, 1965 and ending May 31, 1995.

Any variable, for which output is produced as part of an ORM simulation, could be subject to position analysis. For instance, in the case of stages and for a given day, one single daily value is extracted for every year in the simulation period, yielding a sample of size 30 for that day. An empirical probability distribution function is derived for this sample. There are a total of 365 empirical distributions for daily stages, conditional on the state of the system on June 1, 1999. Next, quantiles are obtained and the time series of percentiles are assembled. These plots define the empirical conditional distribution (percentiles) for one day and describe the evolution of the distribution throughout the forecast year. An example of the unconditional position analysis is presented in Figure 2.

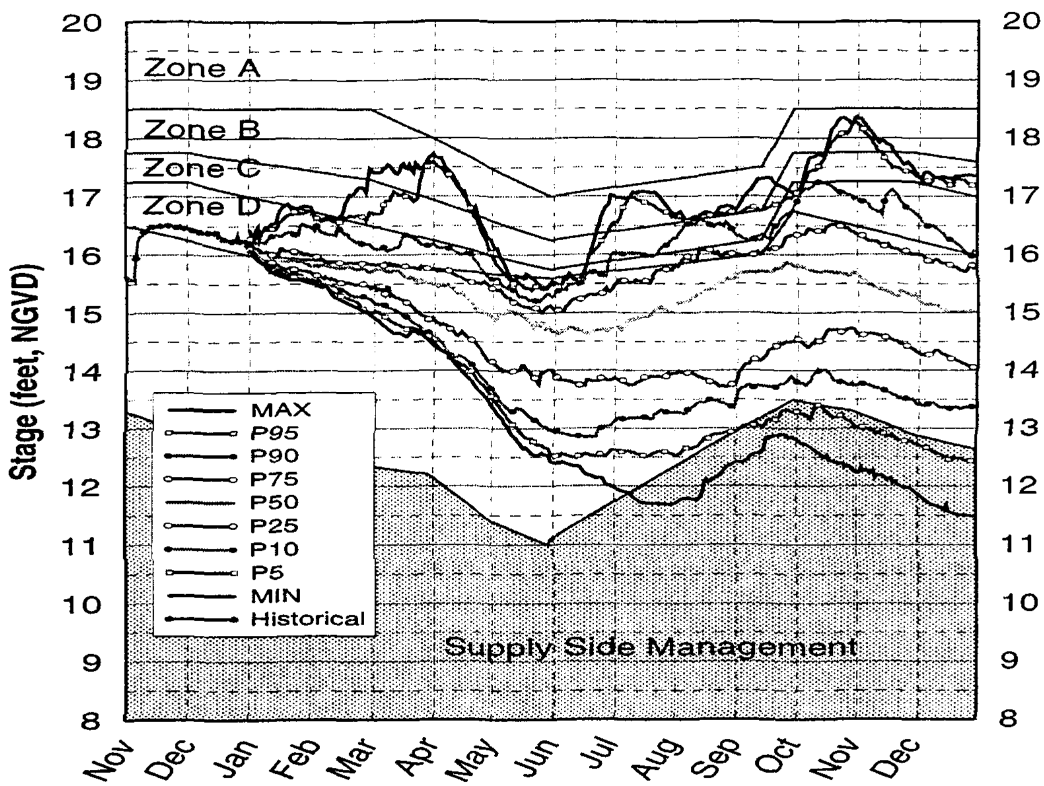

Figure 2. Lake Okeechobee Unconditional Position Analysis Stage Initialized to 16.17 feet on 01/01/1999

CONDITIONAL POSITION ANALYSIS

The methodology adopted to perform conditional position analysis follows the procedures described by Croley (1996). The objective is to estimate the future response of the system in probabilistic terms, given the current state and a future climatic forecast. For instance, it may be important for water managers to know the possible future behavior of daily Lake stages given the state of the system on June 1, 1999, and given a high probability that the SFWMD will be under dry conditions for the next six months.

Croley's (1996) methodology is based on using Climate Outlooks, which are produced by the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC). CPC outlooks are provided for a one-month window for the next month, and 13 3-month overlapping windows going into the future, in one-month increments. The climate outlooks are presented in maps,

which are posted monthly (the 3rd Thursday of the month) (http://www.cpc.ncep.noaa.gov). For each time window, the maps give the probability of rainfall being above normal, normal and below normal. The rainfall values for classification in these three ranges are defined as the lower, middle and upper terciles of a normal distribution fitted to observed rainfall for the last three decades (1961-1990).

Previously published applications of conditional position analysis (Croley, 1996) use climate outlooks for precipitation and temperature, since inflow volumes in those cases are proportional to precipitation and temperature (snow ablation). The conditional position analysis application for south Florida uses the CPC climate outlook for rainfall only, since as temperature increases in south Florida, ET increases and runoff decreases. The presentation for the remainder of this article will focus on rainfall.

The use of climate outlooks in operational hydrology is based on the formulation of structured data sets. Structured data sets are obtained after the available rainfall sample is manipulated to reproduce the climate outlooks. For instance, if the forecast distribution calls for an above normal condition, values in the scenario falling in the above normal range are repeated more frequently than normal or below normal values. Repetition of values forms the structured data set. When a single climate outlook window is considered, the number of replications are given by (Croley 1996):

$$r_A = N_S\, P_A / n_A \,;\; r_B = N_S\, P_B / n_B \,;\; r_N = N_S\, P_N / n_N \qquad (3)$$

where the A, B and N subscripts denote above, below and normal. P_A, P_B and P_N are the climate outlook probabilities, n_A, n_B and n_N are the number of values in the original sample falling in each range, N_S is the structured data set sample size, and r_A, r_B and r_N are the replication factors in each range. For instance, each value in the original sample falling in the above normal range is repeated r_A times. The larger N_S, the closer r_A, r_B and r_N will be to integer values. Note that the following statements are valid:

$$P_N = 1 - P_A - P_B;\; n_N = n - n_A - n_B;\; N_S = r_A n_A + r_B n_B + r_N n_N \qquad (4)$$

where n is the sample size or number of original scenarios. Instead of working with replications and having to select N_S, Croley introduced weights w_A, w_B and w_N, defined as:

$$w_A = P_A\, n / n_A \,;\; w_B = P_B\, n / n_B \,;\; w_N = P_N\, n / n_N \qquad (5)$$

The weights can also be expressed as:

$$w_A = r_A\, n / N_S;\; w_B = r_B\, n / N_S;\; w_N = r_N\, n / N_S \qquad (6)$$

Weights are replication factors re-scaled to the original sample size.

The description of the weights presented so far has dealt only with one climate outlook window. However, the CPC provides outlooks for a total of 14 windows. Now it is necessary to estimate a set of weights w_i, i = 1,..,n. All the weights are different in value and each weight is associated to a particular scenario. They must satisfy simultaneously a maximum of 14 different climate outlook conditions given by

$$\begin{aligned} \hat{P}_A^g &= a_g \\ \hat{P}_B^g &= b_g \end{aligned} \quad , g = 1,\ldots,14 \qquad (7)$$

where $\hat{P}_A^g$ and $\hat{P}_B^g$ represent the forecast probabilities for each forecast window g. Note that the probability of being in the normal range is no longer included, since it is the complement over 1.0 of the sum of the other two probabilities.

The equations in (6) can be generalized to the case when all the replication factors are different as:

$w_i = r_i\, n / N_S$, i = 1,…n **(8)**

$$\sum_{i=1}^{n} w_i = n \qquad \textbf{(9)}$$

The unconditional position analysis case is obtained when all the weights are equal to one.

Let x_i, i=1,..,n represent a sample in which each value is associated to a different scenario. The following expressions are used to estimate statistics for the structured data sets (Croley, 1996):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} w_i\, x_i \qquad (10)$$

$$s^2 = \frac{1}{n}\sum_{i=1}^{n} w_i\,(x_i - \bar{x})^2 \qquad (11)$$

$$\hat{P}[X \le y_j^n] = \hat{P}[X \le x_{i(j)}] = \sum_{m=1}^{j} \frac{w_{i(m)}}{n+1} \quad , j = 1,\ldots,n \qquad (12)$$

where y_j^n are the ordered statistics and i(m) points to the location of the mth ordered statistic in the original sample. For instance, if $y_j^n = x_k$, then i(j) = k. The above equations estimate the mean, standard deviation and empirical cumulative distribution function for the structured data set.

In terms of the weights, the equations in (7) can be written as:

$$\frac{1}{n}\sum_{j=1}^{n} w_j \, I_{\{A_g\}}(x_j^g) = a_g$$
$$\frac{1}{n}\sum_{j=1}^{n} w_j \, I_{\{B_g\}}(x_j^g) = b_g \qquad (13)$$

where $I_{\{.\}}(.)$ is the indicator function. It takes the value of 1 if $x^g_j \in A_g$ and 0 if $x^g_j \notin A_g$, and A_g and B_g represent the set of values above normal and below normal, for window g, respectively. At the same time, x_j^g is the rainfall depth for scenario j, window g. The equations in (13) state that the weights should preserve the apriori forecast probabilities. Note that equations (5) and (13) are equivalent since both are counting the number of values above and below normal.

For the application of conditional position analysis, 30 scenarios are available. A total of 30 weights also need to be computed. There are 30 unknowns and at most 29 equations: one from equation (9) and 28 from (13). There are infinite solutions to this system of equations. The situation becomes more difficult when some of the climate outlooks indicate climatological conditions, which means that the probabilities of being above, below or normal are equal to one third. When this is the case, outlook conditions are not included in the set in (13).

To cope with this problem, Croley (1996) suggests solving the following optimization problem to estimate the weights:

$$\min \sum_{i=1}^{n} (w_i - 1)^2 \qquad (14)$$

subject to the constraints defined by equations (9) and (13).

The optimization problem may produce a solution that is not feasible; namely, some of the weights are negative. Instead of introducing additional non-negativity constraints to the optimization problem, Croley (1996) proposes an iterative process to obtain a feasible solution. The CPC climate outlooks included in equation (13) are assigned a priority. Initially, a solution is attempted using all the constraints. If all the weights are positive, then a solution has been found. If some weights are negative, a new solution is attempted by constraining the weights found negative in the previous step to be equal to zero. If the newly computed weights are all positive, a solution has been found. If negative weights are still present in the solution, the CPC outlook with the lowest priority is dropped, weights made zero in the previous trial are unconstrained, and a new solution is obtained. The process continues in a similar fashion by constraining negative weights to be equal to zero and by dropping additional CPC outlook conditions by priority, until a feasible solution is obtained.

The basic assumption in conditional position analysis is that the weights obtained based on rainfall can be applied to any other variable from the simulation, to obtain the conditional distribution for that variable. Once a solution is found for the weights, equation (12) is used to derive the conditional distribution for each day and produce the time series of percentiles. An example of the conditional position analysis results for Lake Okeechobee is given in Figure 3.

Zero or negative weights are an indication of the inability of the method to produce a conditional distribution if the scenarios corresponding to those weights are kept in the sample.

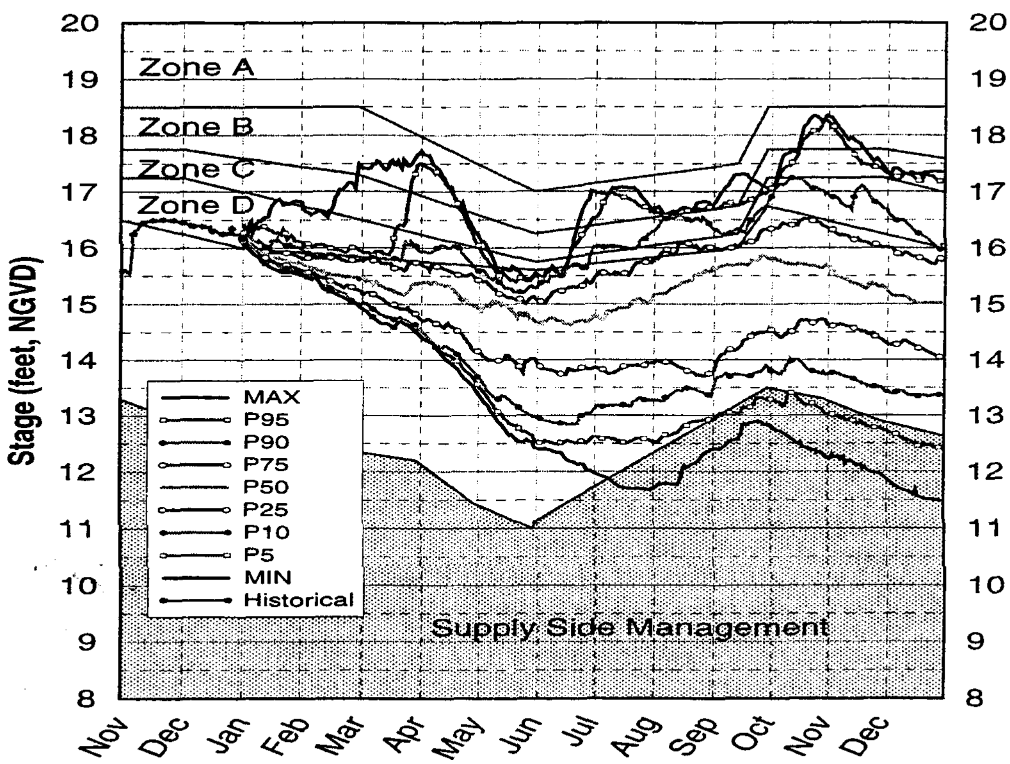

Figure 3. Lake Okeechobee Conditional Position Analysis Stage Initialized to 16.17 feet on 01/01/1999

RESULTS

Unconditional position analysis is a straightforward procedure. Conditional position analysis is a more elaborated process and does not always yields useful results. There is no warranty that conditional position analysis results will be available every month. Some of the problems found in applying conditional position analysis are described as follows:

1. The CPC outlook for south Florida usually provides only a few forecast windows, most of which, especially during the wet season, are termed climatological, indicating normal behavior is expected.
2. Typically, only a few of the CPC outlook probability windows are used to find the solution. In the search for a feasible solution for the weights, climate outlook windows far into the future are dropped first. It might be necessary to drop several outlook conditions before a solution is found.
3. The method might fail to produce a reasonable conditional position analysis solution.
4. Whenever the CPC outlooks for windows including the current month indicate climatological conditions, the SFWMD has opted to not produce the conditional position analysis.
5. Comparison of unconditional and conditional cases may produce unexpected results. For instance, if the CPC outlook calls for a dry condition for the forecast year, some of the conditional percentiles may plot above the corresponding unconditional ones, for some periods of the forecast year, when the opposite behavior is expected. Several reasons explain this behavior: 1) Weights derived for initial months in the forecast year are applied to months well into the forecast year, 2) Weights derived for dry or wet conditions are applied to windows where most of the values fall within the opposite range, and 3) Sample variability in the derived empirical distributions.

Most of the problems described above stem from the fact that weights are associated to scenarios and not to windows or months. If a feasible solution is found, weights associated to each scenario are applied uniformly throughout the forecast year. A possible modification to the method is to allow the weights to vary within the year. Whenever a feasible set is found, weights are applied only to months included in the windows associated with the solution. Weights for the other months are made equal to one. In some cases, changes in weights from one month to the next generate abrupt changes or unexpected behavior in the percentiles. To avoid this, it was decided to implement a linear interpolation scheme for the weights. The weight values for each month are centered in the middle of the month. Values for intermediate days are linearly interpolated between the values at the middle of the months.

The conditional position analysis results produced by the SFWMD are really a combination of conditional and unconditional analysis. The following is a typical set of results produced monthly, for both unconditional and conditional position analyses, provided a valid conditional position analysis solution exists. Examples are given for some cases and they correspond to the position analysis performed on January 1, 1999. Three windows were included initially for the conditional case for January 1, 1999: January, January-March and February-April. The CPC outlook prescribed dry conditions, with the probabilities of being below normal in the range 50-60% and the probabilities of being above normal varying between 3 and 13 %. The final solution for the weights included the January window and the below normal condition for the January-March window. It was required to drop three conditions before a feasible solution was found:

- Time series of percentile traces for Lake Okeechobee (Figures 2 and 3) and for the main WCAs (WCA-1, WCA-2A and WCA-3A). The different zones shown in Figures 2 and 3 are Lake Okeechobee management zones.
- Time series of stages for Lake Okeechobee and for the main WCAs (WCA-1, WCA-2A and WCA-3A), showing the response of the system for dry and wet years. Dry and wet years are selected by performing frequency analysis on the aggregated MDS for the system, for the forecast year under consideration. Figure 4 presents the dry years plot for Lake Okeechobee.
- El Niño years and La Niña years time series plots for Lake Okeechobee and the main WCAs. These graphs are prepared whenever south Florida is expected to be under the influence of mild to strong El Niño or La Niña conditions for part of the forecast year. The graphs are prepared with values from the ORM simulation, corresponding to years on which these conditions were observed historically. Depending on the number of years under each condition, the graphs may show years or percentile traces. These graphs are based on sub sampling according to given criteria. Figure 5 is an example of La Niña years plot for Lake Okeechobee.
- Zone probability graphs for Lake Okeechobee. For the entire year, these graphs give the probability that the stage in Lake Okeechobee falls in any of its management zones. A tabular version of this graph is also produced (Figure 6).

Among all the graphical results produced, the favorites among water managers at the SFWMD are the wet, dry, El Niño and La Niña years plots, since given their experience they can easily relate to the historical behavior response of the system.

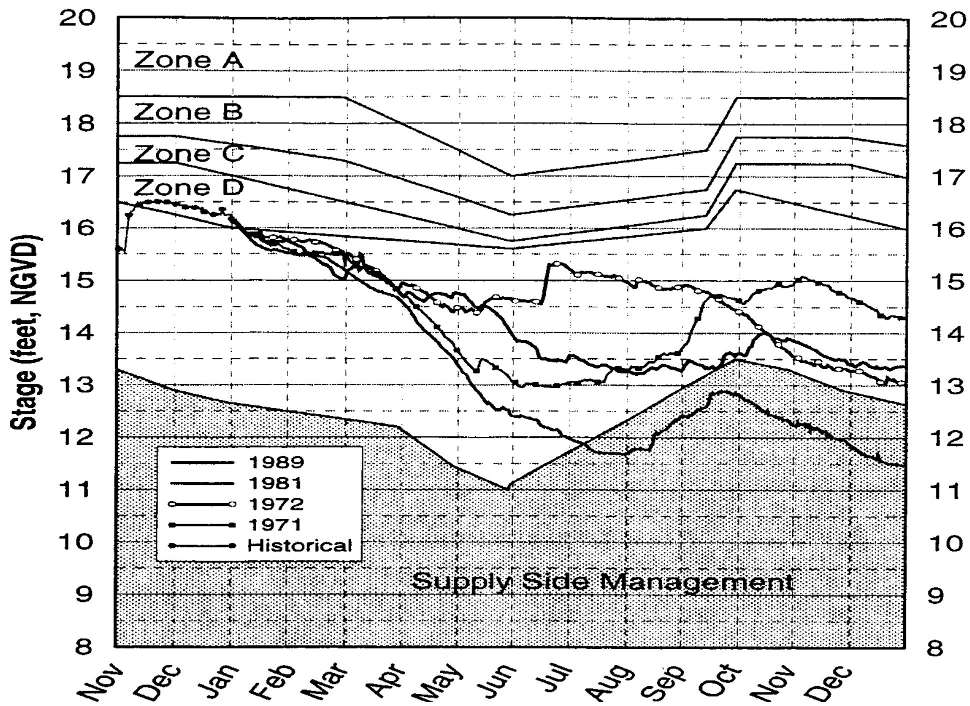

Figure 4. Lake Okeechobee Dry Years Plot - Stage Initialized to 16.17 feet on 01/01/1999

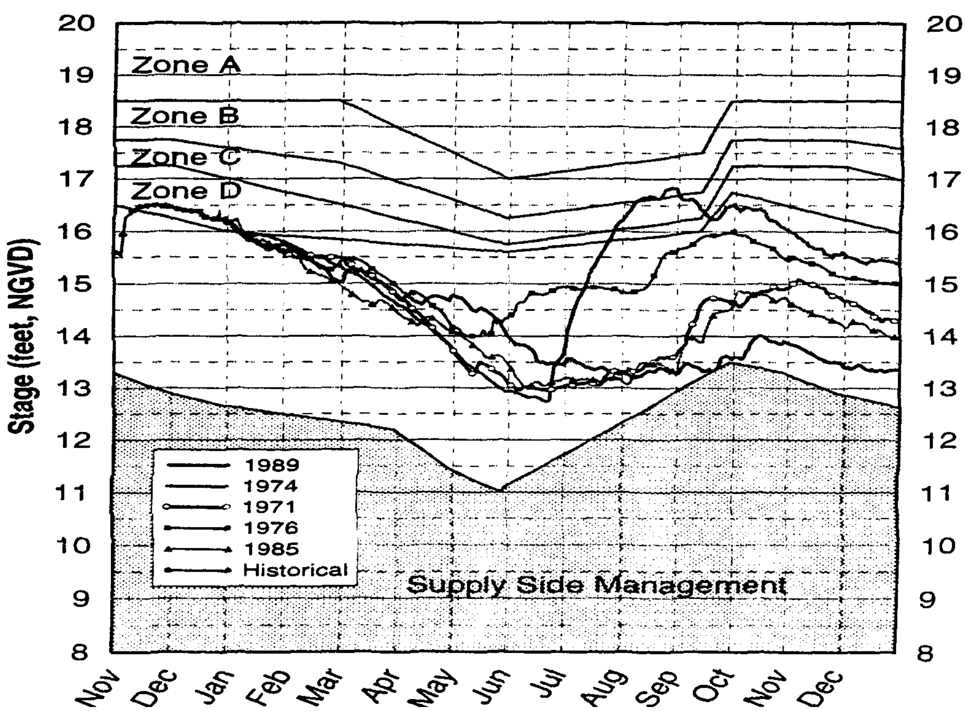

Figure 5. Lake Okeechobee La Niña Years Plot - Stage Initialized to 16.17 feet on 01/01/1999

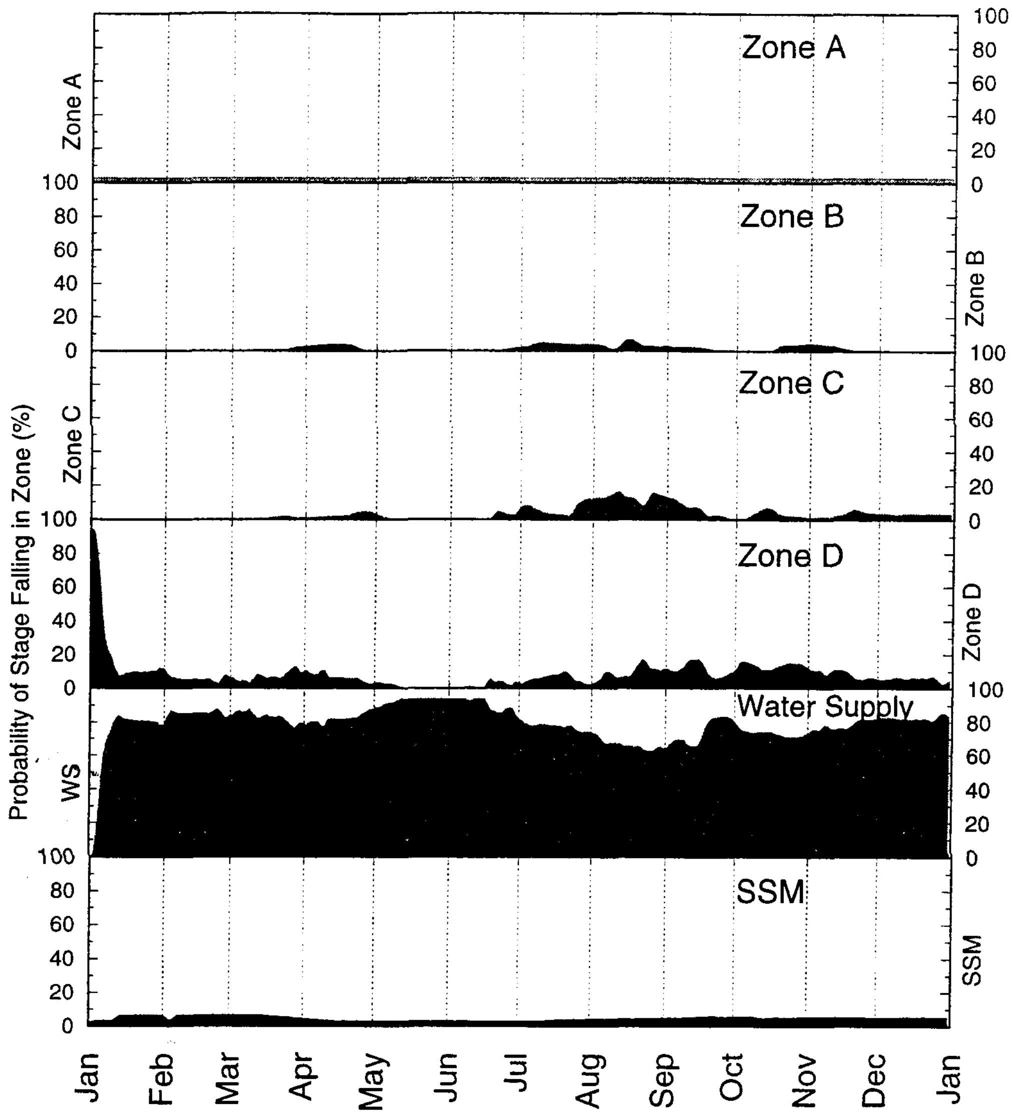

Figure 6. Lake Okeechobee Probability Lines Plot Stage Initialized to 16.17 feet on 01/01/1999

CLOSING REMARKS

The competent and judicious operation of a complex water management system like the SFWMD is no small task. It relies not only upon the knowledge and experience of the operating engineers, but also upon any or all information at

their disposal to assist in the decision making process. Short-term weather forecasts, for example, have been routinely used for years in the daily decision making process. Historically, the seasonal effects of phenomena such as El Niño and La Niña on the regional climate in Florida have been above average and below average precipitation respectively. Unconditional and conditional position analysis are tools to assess the probabilistic state of the SFWMD system for the upcoming months based upon recent climatological history and upon expected climatological trends, such as those generated by El Niño and La Niña conditions. These tools help the operating engineers to adjust and adapt the operations of the system accordingly.

The conditional position analysis results described in this paper are based exclusively upon the CPC Outlooks by the National Climate Data Center. One of the main shortcomings found in the application of the method has been the low rate of success in obtaining a feasible and meaningful solution for the weights. The SFWMD is trying to improve the results by using other forecast products that provide information similar to the CPC forecast. Also, a set of hydro-climatological data, containing a longer period of record (1914-1998), is being assembled for use in operational planning. Finally, the conditional position analysis based on indicators other than rainfall, such as Modified Delta Storage for the Lake, is under consideration.

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APPENDIX K

Appendix K

Details and Procedure for Application of the 2008 LORS Release Guidance Flowcharts

The details of the 2008 LORS release guidance flow charts are described in this Appendix. The data sources and computational methodologies for the flow chart parameters are also presented. This information is necessary for the complete application of the release guidance. In addition, examples of the application procedure are described.

a. Tributary Hydrologic Conditions (THCs). Referencing Figures 7-3 and 7-4, Parts C and D, the first diamond in the flowchart is the "Tributary Hydrologic Conditions". Two measures of the tributary hydrologic conditions are included within the design of the operational flowchart: (1) the Palmer Drought Severity Index (PDSI) for Florida Climate Division 4 or simply the Palmer Index, and (2) the average Lake Okeechobee Net Inflow (LONIN) for the previous two weeks (14 days). Climate Division 4 in south central Florida covers the area located north of Lake Okeechobee.

The Palmer Index indicates prolonged and abnormal periods of moisture deficiency or excess. These moisture anomalies are estimated from rainfall and temperature data available within the region. The advantage of the Palmer Index is that it is standardized to local climate, so it can demonstrate relative greater than (plus) or less than (minus) normal moisture anomalies accumulated over time at a particular time of the year and specified region. Values between -1.5 and 1.5 indicate normal conditions for a particular time of the year. A brief description of the Palmer Index may be found at the following NOAA website: http://www.drought.noaa.gov/palmer.html. The weekly value of the Palmer Index for the implementation of the regulation schedule will be obtained from the Climate Prediction Center (CPC) at the following website: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/palmer_drought/wpdsouth.txt

The daily LONIN provides an estimate of natural and/or controlled Lake inflow/outflow and is an indicator of shorter term hydrologic variability in the Lake tributary basins. A working definition of the LONIN is given by:

LONIN = rf – et + inflow

where rf is the rainfall volume falling directly over the Lake, et is evapotranspiration volume from the Lake marsh and surface areas, and inflow represents the total tributary volume into the Lake.

Due to limitations in data collection, an indirect method is used to estimate the daily LONIN time series. The method is based on re-arranging the mass balance equation for the Lake, by considering all the area enclosed by the Herbert Hoover Dike. The equation applied on a daily basis is:

$$LONIN = \Delta sto + S2/S351 + S3/S354 + S352 + S77 + S308 + L8CP$$

where,

- Δsto is the daily change in storage determined by taking the lake water levels for the current and previous days, and computing the corresponding change in lake storage from the stage-storage relationship. This value is converted from acre-feet to the equivalent average daily inflow (cfs) by dividing by 1.9835
- S2/S351 is the mean daily flow through S2/S351 complex (cfs)
- S3/S354 is the mean daily flow through S3/S354 complex (cfs)
- S352 is the mean daily flow through the S352 structure
- S77 is the mean daily flow through the S77 structure (cfs)
- S308 is the mean daily flow through the S308 (cfs)
- L8CP is the mean daily flow from the Lake to L8 Basin measured at Canal Point, Culvert 10-A (cfs)

All of the structural flow terms in the above equation can be positive (out of the lake) or negative (into the lake). When flows are negative, the effect of back pumping or gravity flow reversal into the Lake is removed from the LONIN estimate.

The Lake Okeechobee stage-storage relationship is presented in Table K-1. The Lake water level and structure flows are retrieved from the Lake Okeechobee and Vicinity Report [http://www.saj.usace.army.mil/h2o/index.htm] which is posted daily. Once the daily time series is formed, the previous mean 14-day inflow is simply formed by computing the average of the daily LONIN for the last 14 days. The mean 14-day inflow is also displayed on the Lake Okeechobee daily report. Negative values indicate ET is greater than rainfall and surface inflow. The LONIN computation is to be made on at least a weekly basis. It may be computed more often under transition or special conditions as needed.

Table K-1. 1968 Stage-Storage relationship for Lake Okeechobee.

Stage (feet, NGVD29)	Storage (1000 ac-ft)	Stage (feet, NGVD29)	Storage (1000 ac-ft)	Stage (feet, NGVD29)	Storage (1000 ac-ft)	Stage (feet, NGVD29)	Storage (1000 ac-ft)
8.00	1442	11.50	2544	15.00	3950	18.50	5525
8.10	1471	11.60	2580	15.10	3993	18.60	5571
8.20	1499	11.70	2615	15.20	4036	18.70	5618
8.30	1528	11.80	2651	15.30	4079	18.80	5664
8.40	1557	11.90	2686	15.40	4122	18.90	5711
8.50	1586	12.00	2722	15.50	4165	19.00	5757
8.60	1614	12.10	2761	15.60	4208	19.10	5804
8.70	1643	12.20	2799	15.70	4251	19.20	5850
8.80	1672	12.30	2838	15.80	4294	19.30	5897
8.90	1700	12.40	2876	15.90	4337	19.40	5943
9.00	1729	12.50	2915	16.00	4380	19.50	5990
9.10	1760	12.60	2954	16.10	4425	19.60	6037
9.20	1791	12.70	2992	16.20	4470	19.70	6083
9.30	1822	12.80	3031	16.30	4515	19.80	6130
9.40	1853	12.90	3069	16.40	4560	19.90	6176
9.50	1884	13.00	3108	16.50	4605	20.00	6223
9.60	1915	13.10	3150	16.60	4650	20.10	6270
9.70	1946	13.20	3192	16.70	4695	20.20	6316
9.80	1977	13.30	3234	16.80	4740	20.30	6363
9.90	2008	13.40	3276	16.90	4785	20.40	6410
10.00	2039	13.50	3317	17.00	4830	20.50	6457
10.10	2072	13.60	3359	17.10	4876	20.60	6503
10.20	2105	13.70	3401	17.20	4923	20.70	6550
10.30	2137	13.80	3443	17.30	4969	20.80	6597
10.40	2170	13.90	3485	17.40	5015	20.90	6643
10.50	2203	14.00	3527	17.50	5062	21.00	6690
10.60	2236	14.10	3569	17.60	5108	21.10	6737
10.70	2269	14.20	3612	17.70	5154	21.20	6784
10.80	2301	14.30	3654	17.80	5200	21.30	6831
10.90	2333	14.40	3696	17.90	5247	21.40	6878
11.00	2366	14.50	3739	18.00	5293	21.50	6925
11.10	2402	14.60	3781	18.10	5339	21.60	6972
11.20	2437	14.70	3823	18.20	5386	21.70	7019
11.30	2473	14.80	3865	18.30	5432	21.80	7066
11.40	2508	14.90	3908	18.40	5479	21.90	7113
						22.00	7160

As a conservative measure of flood protection, the wettest classification of these two regional hydrology indicators is selected to represent the hydrologic conditions in the tributary basin. For example, if the Palmer Index is within the “wet” classification, but the LONIN is within the “normal” classification, then the operational condition will be taken to be "wet". During wet conditions, it is desirable to check regional hydrologic conditions every day. When conditions become very wet, there may be significant advantages for flood protection and environmental considerations to increase flows above the maximum flow rates defined for a given band of the regulation schedule. This type of action should be taken only after the appropriate consideration has been given to all the primary water management objectives. See Section 7-13 for further details. When considering drier than normal conditions, both measures of tributary moisture should indicate dry conditions before tributary hydrologic conditions are defined to be "dry". The tributary hydrologic indicators should be updated weekly (daily if necessary). Refer to Table K-2 below:

Table K-2

Tributary Hydrologic Classification	Palmer Index Class Limits	2-wk mean L.O. Net Inflow Class Limits
Very Wet	3.0 or greater	Greater >= 6000 cfs
Wet	1.5 to 2.99	2500-5999 cfs
Near Normal	-1.49 to 1.49	500-2499 cfs
Dry	-1.5 to -2.99	-5000 – 500 cfs
Very Dry*	-3.0 or less	Less than -5000 cfs

b. Up to 30-Day Meteorological Forecast. The second diamond of Figure 7-4 is the "Up to 30-Day Meteorological Forecast" used in High Lake Management Band, High Sub-Band and Intermediate Sub-Band for determining discharges to tide. The season of the year and the lake water level determine the most appropriate forecast to use. Shorter-range meteorologic and climatological forecasts (a few days up to 1 month) are the most appropriate forecasts to utilize. The "6 – 15 Day Precipitation Outlook" is posted weekly at the SFWMD web page www.sfwmd.gov, under Weather & Water Conditions/Current and Forecast Conditions.

The “Lake level projected to rise to” phrase in the Lake Okeechobee Operational Guidance to Tide (Figure 7-4) can be determined on a daily basis. Information to be considered includes, but is not limited to, the following variables: climate and hydrologic outlooks, position analysis, release constraints due to downstream conditions, actual lake level rate of rise, historical lake levels, and the state of the C&SF system (including the availability of new facilities proposed by the CERP). The SFWMD position analysis is one available tool for integrating much of this information (Appendix J). The lake level projections will be based on the best available tools.

c. Seasonal Climate/Hydrologic Outlook. The third diamond on the flowchart for Part D, Releases to Tide (Estuaries) (Figure 7-4), is the "Seasonal Climate/Hydrologic Outlook". With recent advances in climate prediction, it is now possible to predict, with some level of confidence, the likelihood of the upcoming season having above, below, or near-normal rainfall.

The Seasonal Climate/Hydrologic outlook is based on a quantitative prediction for the expected net inflow into Lake Okeechobee for the next six-month period. This prediction will be updated each month. Values of this outlook represent the expected net gain in storage in the lake after taking into account Evaporation and Transpiration (ET) losses during the six-month period. The various classifications of the net inflow are listed in Table K-3 below, which defines the class limits for classification of the Lake Okeechobee seasonal climate/hydrologic outlook. Utilizing the official CPC climate outlooks together with the Lake Okeechobee historical inflows for the appropriate months allows the quantification of the Lake Okeechobee Net Inflow Outlooks (LONINO).

The current season is defined as the time window starting with the current month and extending six months into the future. Therefore, the Seasonal LONINO always comprises six months. Historical net inflows to Lake Okeechobee are used in the process of producing outlooks for the lake. The monthly data is presented in Table 7-8, following the text. The 3-month window running sum values for Lake Okeechobee net inflow are presented in Table 7-9, following the text, since this data is required later in the analysis.

Table K-3

Classification of Seasonal LONINO

Lake Net Inflow Prediction (million acre-feet)	Equivalent Depth[1] (feet)	Seasonal LONINO
> 0.93	> 2.0	Very Wet
0.71 to 0.93	1.51 to 2.0	Wet
0.35 to 0.70	0.75 to 1.5	Normal
< 0.35	< 0.75	Dry

Section a. provides the definition and method of estimation for the daily time series for the Lake Okeechobee Net Inflow (LONIN). To produce the LONINO for the current season, historical LONIN data (or a summary of it) is transformed by various methods described below so that it is in agreement with the probabilities given by the official CPC climate outlooks or by other federal, state or private organizations. For instance, the rainfall outlook information is posted monthly by the CPC at: (http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/seasonal_forecast.html).

The CPC produces climate outlook windows for a one-month window for the next month and 13 three-month overlapping windows going into the future, in one-month increments. The climate outlooks are presented in maps and for each time period they give the probability of temperature and rainfall being above normal, normal, and below normal. Note that Croley's method (described below) derives the weights based on rainfall data, but they are applied to Lake Okeechobee net inflow data.

Several methods are used to produce the Lake Okeechobee net inflow outlook: (1) Croley's method (1996), (2) SFWMD empirical method, and (3) other experimental forecast methods, such as sub sampling, described in Appendix I. The methodology and an application of Croley's method to the operational hydrology of South Florida are described by Cadavid et al. (1999). A copy of this publication is provided in Appendix J.

As much as possible, all of the above methods should be used any time the 2008 LORS requires a seasonal outlook in order to verify results and detect possible outliers. Also, under certain conditions, Croley's method may not yield a feasible solution. Additionally, as new and improved forecast methods are

1 Volume-depth conversion based on average lake surface area of 467000 acres.

developed, tested, and published, they will be incorporated into the 2008 LORS operational methodology for Lake Okeechobee.

Croley's method uses historical monthly rainfall for the tributary basins into Lake Okeechobee (1914 - 2005), historical Lake Okeechobee net inflows (1914 - 2005) (Table 7-8, following the text), and the CPC outlook probabilities for rainfall. This method is described in detail in Appendices I and J. The input data to Croley's and other methods used here will be updated as soon as it becomes available.

The SFWMD empirical method was developed by the SFWMD as an alternative to Croley's method to utilize the information provided by the CPC when Croley's method yields no feasible solution. This method is described in detail in Appendix I.

The last method is derived by sub sampling from the Lake net inflow historical sample, according to different global indicators which have been found to influence south Florida climate. These indicators, also known as teleconnections (Obeysekera et al, 2000), include El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) and the Atlantic Multi-decadal Oscillation (AMO). They reflect temperature anomalies (above/below normal conditions) for different regions in the earth's oceans. For instance, based on research by Enfield et al. (2001) and by Mestas-Nuñez et al. (2003), the currently preferred method to produce LONINO values extracts from the Lake net inflow historical sample monthly values which fall on the same category as the current and forecast indicators for AMO and ENSO combined. At of the end of 2007, AMO was in the positive phase, while ENSO was under negative (La Niña) conditions. The outlooks are computed as the expected values of monthly volumes, considering only those months for which the selected indicators apply.

d. Multi-Seasonal Climate/Hydrologic Outlook. The fourth diamond of Figures 7-3 and 7-4 is the "Multi-Seasonal Climate/Hydrologic Outlook". The onset of hydrologic drought in Florida is often initiated with below normal wet season (May - October) rainfall which leads to lower availability of water supply for the upcoming dry season months (November-April). This is especially crucial if a La Niña condition develops in the equatorial Pacific Ocean during the following winter months. On the other hand, above normal wet season rainfall often leads to the need for regulatory discharges from Lake Okeechobee during the same dry season. This latter event is especially crucial if an El Niño condition develops in the tropical Pacific during the

of the key decision parameters.

This Multi-Seasonal LONINO is based on the expected inflow during the remainder of the current hydrologic (wet or dry) season and the entire six months of the next season. The multi-seasonal hydrologic outlook is therefore defined as either: (1) the remainder of the wet season and the upcoming dry season,

season. The last 1 to 2 months of a particular season are considered as transition months. During the transition from 'dry season' to 'wet season', in March and April, if the multi-seasonal climate outlooks indicate an increased likelihood of below normal rainfall for the next two consecutive seasons (May to April), then the multi-seasonal outlook should be formed using the climate forecasts for the upcoming May to April period. Likewise during the transition from 'wet season' to 'dry season', in September and October, if the multi-seasonal climate outlooks indicate an increased likelihood of above normal rainfall for the upcoming two consecutive seasons (November to October), then the multi-seasonal outlook should be formed using the climate forecasts for the upcoming November to October period. The multi-seasonal forecasts for May through April become available by mid-March, while the multi-seasonal forecasts for November through October become available by mid-September. This is the earliest date that the transition should be made.

The primary variable is the quantitative estimate of LONIN

duration of the multi-seasonal window varies between 7 and 12 months.

The production of the Lake Okeechobee net inflow outlook for the multi-seasonal window utilizes the same materials and procedures as in the seasonal outlook: CPC outlook probabilities for rainfall in south Florida, historical Lake Okeechobee net inflow data for the period 1914 - 2005, current climatic indices for ENSO, AMO and PDO, and the summary of the historical Lake Okeechobee net inflow data in the form of the tercile midpoints presented in Appendix I, Tables I-1 and I-2. The methods used to compute the multi-seasonal outlook are the same, with some variations. Croley's method is applied in a similar fashion, with the exception that additional months are used to compute the multi-seasonal Lake Okeechobee net inflow. In the SFWMD empirical method, the methodology presented for a window of 6-month duration is generalized to a duration between 7 and 12 months. See Appendix I for further details on these two methods.

Table K-4 defines the class limits for classification of the Multi-Seasonal Lake Okeechobee Net Inflow Outlook.

Table K-4

Classification of the Multi-Seasonal LONINO

Lake Inflow Prediction (million acre-feet)	Equivalent Depth (feet)[2]	Multi-Seasonal LONINO
> 2.0	> 4.3	Very Wet
1.18 to 2.0	2.51 to 4.3	Wet
0.5 to 1.17	1.1 to 2.5	Normal
< 0.5	< 1.1	Dry

e. Example Applications of the Release Guidance Flow Charts.

Input data used in the following three examples was obtained from historical records. The Seasonal and Multi-Seasonal LONINO were determined using sub-sampling based on AMO and ENSO. The Forecast is assumed to be formed at the beginning of each corresponding month. For the examples no corrections to LONINO were applied for antecedent conditions, neither for what actually took place in between the first day of the month or for the actual date on which the decision making process is applied.

2 Volume-depth conversion based on average lake surface area of 467000 acres.

1. Part C: Establish Allowable Lake Okeechobee Releases to the Water Conservation Areas

Date	09/23/2004	11/09/2004	04/20/2005
Lake Okeechobee Stage (feet)	15.73	16.68	15.21
Part B Band	Low	Intermediate	Low
PDSI	2.68/Wet	2.48/Wet	2.09/Wet
LONIN 14-day Moving Average flow (cfs)	26987/Very Wet	-585/Dry	1968/Normal
THC	Very Wet	Wet	Wet
AMO	+	+	+
ENSO	Neutral	Neutral	Neutral
Seasonal LONINO (ft)	N/A	N/A	N/A
Multi-Seasonal LONINO (ft)	2.60/Wet	N/A	4.22/Wet
WCAs Stage Constraint	All WCAs are below regulation schedules	WCA-3A stage is below max of schedule plus 0.25 ft.	All WCAs are slightly above regulation schedules
STA Treatment Capacity Constraint	STA-3/4 treatment capacity is available	STA-3/4 treatment capacity is limited	STA 3/4 treatment capacity is unavailable
Recommended Releases through C-10A, to L8/C-51 to tide	Subject to available conveyance capacity	Subject to available conveyance capacity	Subject to available conveyance capacity
Recommended Release	Maximum practicable to WCAs	Release according to available STA-3/4 treatment capacity	No releases to WCAs

2. Part D: Establish Allowable Lake Okeechobee Releases to Tide (Estuaries)

Date	09/23/2004	11/09/2004	04/20/2005
Lake Okeechobee Stage (feet)	15.73	16.68	15.21
Part B Band (sub-band)	Low (Upper)	Intermediate	Low (Upper)
PDSI	2.68/Wet	2.48/Wet	2.09/Wet
LONIN 14-day Moving Average flow (cfs)	26987/Very Wet	-585/Dry	1968/Normal
THC	Very Wet	Wet	Wet
Lake stage within 1.0 ft of Intermediate	Yes	N/A	N/A
Up to 30 day meteorological forecast	N/A	N/A	N?A
AMO	+	+	+
ENSO	Neutral	Neutral	Neutral
Seasonal LONINO (ft)	2.60/Very Wet	N/A	N/A
Multi-Seasonal LONINO (ft)	N/A	N/A	4.22/Wet
Recommended Releases through C-10A, to L8/C-51 to tide	Subject to available conveyance capacity	Subject to available conveyance capacity	Subject to available conveyance capacity
Recommended Releases through S-77, S-79 & S-80	S-77 Up to 4000 cfs S-80 Up to 1800 cfs	S-77 Up to 4000 cfs S-80 Up to 1800 cfs	S-79 Up to 3000 cfs S-80 Up to 1170 cfs

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