Governor Askew - Gentlemen of the Cabinet:

My sole purpose for being here is to help solve some of the environmental problems of Florida. Environment - or human ecology - is complex for it involves not only the intricacies and injunctions of nature but also the culture and the needs of man. As a humanistic ecologist with 20 years professional involvement in Florida, I am satisfied that most of the problems you must solve in this conference and in your other responsibilities have both their roots and their solutions in ecologic phenomena. To ecology as a major parameter in this problem I would add one other - ethics - as expressed in love of the land and of each other.

My special topic is the water resources of southern Florida - the essential on which all life depends. In that area some water quantity problems are:

The canalization of the lower Kissimmee River is as clear an abuse of the public's water supply and wildlife resources as we have in Florida. That canal now transports water to Lake Okeechobee so rapidly that much must be wasted to tidewater for the lake can't hold it and it can't over-spill the southern rim into the Everglades. Most of the marshes of the river basin have been destroyed, the coastal estuaries suffer from mud-laden fresh water surcharges, and the lake cannot be managed even in accord with its established schedules. I am sure that we shall, in this decade, have to spend millions to restore some of the Kissimmee's lost values - values which originally came gratis.
Another large area in multiple stress is the water basin of the Everglades. Here despite expenditures of several hundred millions, we have witnessed a switch from flood to drought in 9 months. This discourages confidence in this system on which south Florida man and wildlife depend.

In the interest of expanded land use - for farm and city - we have balkanized the Florida Everglades to a degree which threatens its own existence, a national park, and the water supply of south Floridians. We are told by the project designers that south Florida may experience critical water shortages by 1976. In light of the present drought it would be nice if we could depend on that optimistic prediction.

The Everglades is too much shrunken. A remnant half of the original glades must now provide flood protection and water to users in the drained half as well as those on the natural uplands. Because we have a boy doing a man's job we saw the yo-yo principle invoked from March to December of 1970. Man has too much occupied the flood plain - an act which often produces short-term gain and long-term loss. It is an extension of our good fortune that no city of a million people exists in the Everglades National Park.

We have further plans to stress the system. Because we have markedly lowered ground water levels in south Dade and in the Taylor Slough Drainage of the Park, we must now tap Conservation Area 3 to re-supply these non-riparian areas. And we plan yet more canals in south Dade (C-109 and C-110). We also have congressional authorization to drain the very large wetland known as Southwest Dade - a further invitation to trouble.

A plan in the wings for Martin County would pump excess water from a large non-riparian area to Lake Okeechobee when the lake doesn't need it and take water from the lake when riparian users are sitting on dry.
The water supply situation alone is enough cause for objection to drainage of the Fahkahatchee Strand by developers and of the eastern Big Cypress by works associated with a major airport.

We must not only halt all further drainages from the Everglades - we must hold what we have and expand its wetlands wherever possible. Preservation of the Big Cypress is an outstanding need in this. Canals such as 302 planned for Conservation Area 2A should not be built. Conservation Area 3 is already struggling along with overdrainage from its interior canals. We shall have to reflood drained areas.

Robert Ruark once wrote that we ain't paying no more money to no more admirals to run no more battleships onto no more sandbanks. We should as lucidly inform canal builders that we intend hereafter to spend our public monies on useful purposes such as retaining our water resources.

As an aside we have generated a formidable heritage for subsequent generations by consumption of the everglades muck. Soil authorities give it a life of 30 years. We have concurrently destroyed the mechanism which produced that much over thousands of years.

Much of the Everglades is besieged by imported trees - Brazilian pepper, Australian pine and Melaleuca. Unless their spread is stopped the next generation of glades watchers will see a vastly different world. Certainly no agency of government should encourage the planting of these or other imported trouble-makers; the practice should be forbidden by law.

A problem allied to water quantity is water quality. In the Kissimmee-Glades basin Apopka-ese conditions are advancing like a wave. With stabilization of the Kissimmee Lakes, increasing nutrient input into the valley, destruction of the Kissimmee marshes and the rapid transport of upper valley nutrients to Lake Okeechobee we can expect nothing else.
A CRITIQUE OF WATER MANAGEMENT IN SOUTH FLORIDA

Shirt-Sleeve Symposium
South Florida Water Management District
November 20-21, 1980
Ft. Lauderdale, Florida

Arthur R. Marshall
Ecologist

INTRODUCTION

I consider my time on this platform a moment of grace for me – however fleeting. I genuinely thank the Board for inviting me. I suspect it was not easy for them to do. I consider their invitation a praiseworthy acknowledgement of the need for full and open communications between all parties in our difficult times – the kinds of communications essential not only to improving water management in south Florida but in respect to all the troubles of the region.

I hope, further, that this seminar is only the first of a series of similar enterprises.

Having just 20 minutes, I shall move rapidly ahead. For those who wish more details than I can give here, I shall supply your moderator with a copy of my recent paper, "Repairing the Florida Everglades Basin." Please note 'Repairing' – not 'Restoring.' Repairing is possible; restoring is not.

GOALS FOR IMPROVING WATER MANAGEMENT

In any human struggle we should first define its objectives – its goals. Where do we want to go?

There are six major goals which I consider top priorities in improving management of the water in the Everglades system:

1) Regeneration of muck in the Everglades. Muck – however prosaic it may seem – is the star indicator of the health of the system. Fortunately for all of us, it is a diagnostic sign which we can readily observe.

2) Reestablishment of wetland vegetation. Wetland vegetation is of course a necessary precursor to muck regeneration.

3) Enlarged populations of fresh water organisms – fish and shell fish – which are essential foods for people and wildlife.

4) Relief of stress on the endangered species of the Everglades, and on its mammalian species which are periodically decimated by high waters.
5) Enlarged populations of marine fishes and shell fishes in Florida Bay.

6) Enhanced recharge of the Biscayne Aquifer.

These all involve natural resources of increasing importance to South Florida's people and its wildlife. They are all interrelated by ecologic processes to such an extent that accomplishing one of them will cause improvement in all the rest. Conversely, failure to achieve any one of them will lead to failure in all the rest.

Ultimately, many Floridians will evaluate these objectives in terms of their worth to mankind. The values of four of them - muck for food production; marine and fresh water fishes for human food; recharge of the Biscayne Aquifer for water supply - are evident in our world of increasing needs and diminishing resources.

It is not easy to recognize the value to people of wetland vegetation. Its contribution to the quality of drinking water - as I shall mention later - are also little recognized.

The value of birds and other wildlife? Some of us simply enjoy them. Others recognize that the well being of the Everglades's wildlife is linked in complex ways with the well-being of the people on the Gold and Treasure Coasts. Everglades wildlife thrives on extended hydroperiods; on wetland vegetation; on the generation of muck and on the bountiful production of marine and fresh water organisms - just as people do.

INEVITABLE ECOCLOGIC PROCESSES

My second purpose here is to describe a particular set of ecologic functions and processes which cannot be ignored in seeking to achieve the six objectives. In whatever decision result from this conference and others to follow, these processes will be functioning - beneficially or adversely.

The first is "sheet flow." Some refer to it as "extended hydroperiods." I prefer the "River of Grass" because that term implies vital ecologic functions which neither of the two physical terms provide.

In order to generate muck, seven to eight months of surface sheet flow are required. Four or five months of surface flooding will produce wetland vegetation. Another three or four months of flooding, or at least of saturation, are required to convert the annual detritus (leaf fall) of wetland vegetation into muck. If wetland detritus is dried soon after the rainy season, it will pass by means of oxidation into the atmosphere rather than into the muck bed.

If we achieve an extension of hydroperiod sufficient to produce muck, the Everglades system will also produce more forage fishes and shell fishes for wading birds and other wildlife; increases in the larger fresh water fishes and the marine fishes sought by man; increased recharges of shallow aquifers.
There is also the possibility - in accord with concepts developed by Dr. Patrick Cannon - that additional rainfall on south Florida will be induced.

When we have hydroperiod shortfalls, muck is decomposed rather than produced. This not only releases the nutrients stored in the plant tissues - as is well known - but also leads to the transport of finely divided muck particles in flowing canal waters. The blankets of ooze lying on the quiet bottoms of the St. Lucie Estuary have for many years demonstrated the effects of that kind of transport.

It is also possible that decomposition of muck and transport of its fine particles add to the organic load in Miami's drinking water which requires chlorine treatment. This has not to my knowledge been investigated, but it surely should be. If this does happen, then we have a seventh major objective beyond the six I have listed - a reduction in that organic load by replacing muck decomposition with its regeneration through an extension of the hydroperiod.

An extremely important character of sheet flow is that it involves moving rather than standing water. Water moving through the Everglades, no matter how slowly, produces muck. Standing water produces ooze as is well-demonstrated in Conservation Area 2A. I do not know why this is so; I can find no one who does. The differences in the products of water moving - even at the slow rate of 20 feet per day - and water standing are marked - muck or ooze. I think it is akin to the dramatic difference between being old and being dead.

The adherence to water regulation schedules in the three Conservation Areas is antithetical to extension of sheet flow in the Everglades. It is not possible to manage water with emphasis being placed on the vertical component and to recreate extended sheet flow on a horizontal plane through the system.

None of these characteristics of sheet flow are difficult to understand. They do require more contemplation than we can enjoy here and I ask that you do that in your leisure.

THE MARSHALL PLAN

There are other issues in the Everglades system but these are enough to indicate my thinking, Time shortens and I now move on to the "Marshall Plan" for improving water management in the system.

I begin with the Kissimmee Lakes. Their existing water quality problem - as exemplified by Lake Tohopekaliga - must be resolved by some means other than discharge of wastes into them. Some years ago, there was widespread acknowledgement that "dilution is no solution to pollution."

I would dechannelize the lower Kissimmee. In addition to the benefits envisioned by the Legislature - benefits expected largely within the lower valley and Lake Okeechobee - dechannelization has great potential for slowing the inflow of the whole valley into Lake Okeechobee. Not only would that be desirable in periods of water deficiency as Okeechobee is now experiencing, but it could also
provide an extension of sheet flow south of the lake to enable muck regeneration now and in the future.

Following removal of the "hump" in the Miami Canal, I would pass Kissimmee-Okeechobee waters through the present agricultural area via that canal as slowly as possible into the Holey Land and Rotenberger Tracts. Where it is possible, I would also return good quality waters which now go to tide, and which are not necessary to maintenance of marine productivity, to the Holey Land and Rotenberger Tracts or to Conservation Area Three. The purpose of such re-diversions would not be solely to increase the depth of waters in the rainy season, but primarily to extend the period of sheet flow after the end of the rains.

I would sheet the water through Conservation Area Three by: culverting its north levee and Alligator Alley; by blocking the Miami Canal, and the Alley's borrow canal and the Conveyance Canal for L-67-A; and by opening the S-12 structures for flow into Everglades National Park.

I would establish hydrologic connections between Area Three and the Big Cypress Preserve. I would reestablish sheet flow into the North East Shark River Slough. I would refill that portion of Canal 111 which lies under U.S. Highway 1, and all of Canals 109 and 110 now existing.

I would restore the Turner River in the Big Cypress Fresh Water Preserve.

As the agricultural muck diminishes over the years around the Holey Land and Rotenberger Tracts, I would periodically move the line of reflooding northward.

These actions can return sheet flow to hundreds and perhaps a thousand square miles of the Everglades system. They can teach us how to restore muck; the water regimes which are required to do it; and how rapidly we can do it with the nutrient-enriched waters we have available in the system today.

Every objective I presented earlier would be benefitted.

SUPER SOLAR BENEFITS

All of the benefits achieved by the plan of repair would derive from solar energy. Which is itself another prime objective of our day.

The great "River of Grass" served as a giant "solar panel" in the pristine Everglades. All of the rich resources of the Everglades were produced by solar energy operating through its surface sheet flow. The sun is still there.

Restoration of sheet flow can utilize enormous amounts of solar energy to produce the valuable benefits I have described. Solar panels on the roofs of the Gold Coast would provide hot water only – no muck; no aquifer recharge; no food for wildlife or people; no improvement in water quality. In further comparison, in terms of total solar energy utilized, a solar panel on every roof of the Gold and Treasure Coasts would fall far short of the amount utilized by a repaired "River of Grass."
OTHER SUBSCRIBERS

There are others beside myself who are moving in these directions, or at least analyzing the possibilities:

The National Park Service, the Fish and Wildlife Service, the Corps of Engineers and the East Everglades Resources Planning Project in their reviews of the North East Shark River Slough.

The Fish and Wildlife Service in its review of water supply augmentation in South Florida.

The Florida Game and Fresh Water Fish Commission in its recent publication on the Fishery Resources of Florida.


Dan Haunert ventured into possibilities for conserving fresh waters for return to the Everglades in his review of the effects of fresh water discharges into the St. Lucie Estuary - 1980.

The Governing Board of the District and the Corps of Engineers have certainly moved on the sheet flow issue by construction of S-339, S-140 and allied structures in Conservation Area 3A. They are also involved in the matter by the planned three-year drawdown of Conservation Area 2A.

And, of course there are legions of conservationists in and out of Florida who are eager for the repair of the Florida Everglades.

All of which are thoughts related to the well-being of south Floridians and south Florida's wildlife from an ecologic derivation.

GOOD NEWS

In the event efforts are implemented to extend sheet flow in the Everglades, I suggest that these items be monitored.

Recharge of the Biscayne Aquifer
 increases in muck
 Extent of reestablishment of sheet flow
 Extent of reestablishment of wetland vegetation
 Ooze siltation in the St. Lucie Estuary, Conservation Area 2A and the ponding which occurs just north of the Tamiami Trail in Conservation Area 3A
 Water quality in respect to organic loading in Miami's well fields
 Responses of bird life and terrestrial wildlife
 Responses of fresh water and marine animal populations for both
d bird forage and human food
 Effects on rainfall under the concepts of Dr. Gannon
 Effects on exotic trees - Melaleuca, Brazilian pepper, etc.
In connection with these, I have long thought that researchers who follow the condition of the Everglades would find monitoring its recovery much more enjoyable than monitoring its degradation.

I thank each of you. Have fun in your shirt sleeves as I have had in mine.
Editorial

Partial Kissimmee Restoration Plan
Just Won’t Hold Water

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Frank Falin (305) 234-8401

Florida Sportsman August 1982

"For He maketh small the drops of water; they pour down rain according to the vapour thereof ... and distil upon man abundantly" (Job 36:27).

Wisdom penned more than 3,000 years ago describes a natural process that is a vital part of the South Florida ecosystem.

But man doth not comprehend the system and so he heweth out gulleys in the land to draineth off the water and, alas, the rain is no more.

And another chapter is added to the saga of South Florida’s ravaged natural resources. We are now warned that large-scale drainage of wetlands has a connection with a decrease in rainfall that threatens to plunge the region into a series of long-term droughts.

Art Marshall, Florida ecologist, is advancing the theory that loss of wetlands has crippled the rain-generating mechanism responsible for the annual rainy season. The summer rains, explains Marshall, are dependent upon vast amounts of water covering the land as it did in past years. The wetlands themselves generate rainfall by giving up large quantities of water to evaporation under the hot summer sun. When sufficient water is present on the land, the daily buildup of water vapor becomes great enough by mid-afternoon to cause rain to fall, bringing with it additional vapor that has drifted inland from both coasts.

But with ever-decreasing wetlands, this surface-heating and evaporation pattern does not function as it formerly did. South Florida does not receive the quantity of rainfall during the rainy season that it did when sheetflow covered the land from the Kissimmee lakes to Florida Bay.

Marshall’s figures show that rainfall in the Kissimmee River basin has become less each year since the Kissimmee River was channelized by the Army Corps of Engineers, draining 32,000 acres of marshland. As a consequence, the channelized river is delivering less and less water to Lake Okeechobee. In the 1950s, about 1.2 million acre-feet of water each year was going into the lake via the river. Last year, the figure was down to only 71,000 acre-feet, a drastic reduction.

Since the lake serves as the primary water reservoir for South Florida, such statistics strongly cry out for de-channelization of the river, a project that has been contemplated and much-studied for nearly a decade.

In 1971, the 102-mile-long meandering, shallow river was engineered into a 56-mile-long deep, straight ditch. Only a few months later, the resulting environmental problems prompted a series of studies which led, in 1976, to a bill by the Florida legislature authorizing de-channelization and establishing the Kissimmee River Coordinating Council to work toward that end. In 1978, the 95th Congress asked the Corps to study the possibility of de-channelization.

But the wheels of de-progress do not turn very fast. And while it took the Corps only a few months to complete its channelization study in 1948, its $1.8 million de-channelization study is now in its fourth year as it chugs along slowly along. Originally scheduled for completion this month, the three-stage study is now only at the end of stage two.

Joseph Burns, Corps project manager, said that although state officials had asked that the study be speeded up, such would be an impossibility.

"We are constrained by our planning procedures which now schedule the final report to be completed by March 1984. We are actually behind our own timetable because we’re using a large data management system that has not been used for large projects, and we had some problems developing it. We have now finished evaluating our wide range of alternatives and we are now taking the best of the alternatives and doing a more detailed analysis," Burns said.
While the Corps has been analyzing various ways to shove the dirt back into the ditch, much of the dirt has been sold and hauled away by landowners along the river. But it really doesn’t matter anyway, because the Corps gave the dirt away when it removed it from the riverbed. Landowners along the federal easement were given the spoil piles and many sold the shell-dirt mixture by the truckload.

“When you take dirt out of a project, you don’t anticipate you’ll be needing it again, and I really don’t know how this aspect of the matter will be handled. This is the first time I’ve ever had the job of actually looking at filling back in a federal project,” said Burns.

If the project is approved, the state will spend many thousands of dollars to buy back its dirt and to have additional dirt brought in. The cost of the land and dirt now required for complete de-channelization is estimated at $32 million, with another $30 million necessary to complete the project.

But in addition to complete de-channelization, there are 12 other options being considered by the bureaucrats. Marshall said he considers only three of the Corps’ alternatives as acceptable: complete backfilling, partial backfilling and plugging in that order.

Both the Corps and the South Florida Water Management District have indicated that their idea of restoration is simply to pool water behind five lift gates on the lower Kissimmee, thereby re-flooding about 6,000 acres of marsh. A proposal to carry out such a plan was made by the water managers in May. The idea pulled into the station right on schedule, just four months before the September due date for the council’s decision on restoration of the river.

We cannot allow this proposal to serve as a political compromise that thwarts the real restoration that we need.

Marshall said that the token plan would not have significant impact on South Florida’s water problems.

“Even with an additional 6,000 acres of wetlands, we would still fall far short of restoring that valley. We need to acquire at least 30,000 acres of land to do that,” he said.

“If we don’t do it, rainfall over the valley will continue to slide, and Lake Okeechobee will not be an adequate reservoir.”

The consequences would be many and shuddersome—ranging from potential drying up of the Everglades to threatened destruction of historic ecosystems in Everglades National Park and Florida Bay. Besides that, a few million people in South Florida would like to continue drinking water every day.
Scientists Discount Drought Theory

By Jeffery Kahn

The drainage of the Kissimmee River Valley probably has not diminished rainfall but it might have reduced water supplies, the experts who control South Florida water were told yesterday.

Responding to a Sports Illustrated article that claimed the state’s drought is partially man-made, water managers called in a team of scientists to analyze Florida’s 1981 drought.

Scientists criticized the thesis that drainage of the Kissimmee River Valley wetlands has reduced critical moisture which triggered rainfall. However, they said, the drainage was not accomplished without a price.

The 1960s drainage project solved a flood problem but might have created a water supply problem, scientists said. Since the channelization of the river was completed in 1968, less runoff has flowed down the river into Lake Okeechobee, they said.

Lake Okeechobee’s historically low level during the past year has been at the heart of the water shortage.

Gov. Bob Graham presided over the discussion during a South Florida Water Management District board meeting in West Palm Beach.

Graham was noncommittal on the issue of whether man’s drainage of the state has created a drier climate. Years ago, his late father, state Sen. Ernest Graham, was an advocate of channelizing the Kissimmee and draining wetlands to create more pastureland. Like many landowners in the Kissimmee Valley, Graham was a cattleman.

“I am not sure it was intended to do that,” the governor said.

He endorsed the idea of calling a scientific conference to more thoroughly examine man’s alteration of the Florida climate. It will be held in Gainesville May 12-14.

If drainage systems were to be seen as projects that can diminish rainfall, future drainage plans likely would meet serious opposition. Recognizing that, a gathering of agricultural, environmental, regulatory and political leaders joined Graham and the WMD yesterday.

Among them were Peter Mott of the Florida Audubon Society, Johnson Jones of the Florida Wildlife Federation, Dalton Yancey of the Florida Sugar Cane League, state Rep. Frank Messersmith (R-Lake Worth) and Rose Mary Mecham, a co-author of the Sports Illustrated article.

Graham said the importance of the issue is how it affects impending plans to restore the Kissimmee River Valley.

By the end of the year, Graham said, the Army Corps of Engineers will announce its plan for the restoration of the valley and the state will have to decide how it will repair the damage done by the channelization project.

The two favored alternatives include creating a system of impoundments to store water along the course of the river, or a more natural course. Fill would be put into the straightened river, causing it to spread and meander over a flood plain similar to its historic course.

Dr. James Heaney, director of the University of Florida’s Florida Water Resources Research Institute, helped write the article. Heaney said the flooding in the valley.

Heaney said you are experiencing some loss of rainfall due to a loss of evaporation. You are getting less runoff per inch of rainfall since the Kissimmee development project.

“On the long-term average, you are losing water. We are paying a penalty.”

Heaney said if the trend of reduced runoff from the valley continues, “this is something to worry about.”

Huber said the drought in South Florida probably was caused by a lack of tropical storms and hurricanes during the 1970s. From 1881 to 1980, about 50 percent of the state’s rainfall was from hurricanes and tropical storms. The lack of hurricanes during the past decade is relatively improbable, he said.

“Most people would consider that a statistical anomaly,” Huber said in an interview. The scientists who quoted him as saying that the kissimmee was “little credence.”

That thesis is that water vapor from relatively small wetland areas can trigger substantial rainfall.

“I would be very surprised if that claim was true, because it has been found that variations in local evaporation have any measurable influence on the rainfall of South Florida,” Huber said.

Huber said the drought in South Florida during the past year was not confined to this region. The entire Southeast suffered a drought in 1981, he said.

“I don’t think we can attribute this drought to the phenomenon known in fact it was occurring throughout the Southeast.”

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Partial Kissimmee Restoration Plan
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Standing Room Only At Drainage/Rainfall Conference

As late winter became early spring 1982, the national magazine Sports Illustrated spotlighted the State of Florida with yet another article by Robert H. Boyle and Rose Mary Mecham titled "Anatomy of a Man-made Drought" (March 15, 1982; for the 1981 article, "There's Trouble in Paradise", see Sports Illustrated, February 9, 1981). The gist of this year's article is that the slowly moving sheet of shallow water that historically flowed in annual cycles from the Kissimmee River basin south into Lake Okeechobee and then spilled into the Everglades was the key to the region's abundant rainfall, and that the vast systems of drainage existing today in South Florida to allow for development and large scale agriculture have essentially impared the area's "rain machine".

In response to the stir caused by Boyle and Mecham article, the Florida Water Resources Research Center hosted a one-day conference entitled REGIONAL INFLUENCE OF

DRAINAGE ON THE HYDROLOGIC CYCLE IN FLORIDA on May 14 at the Reitz Union University of Florida. The overflow attendance was ample evidence of the genuine interest in the topic of inadvertent water modification in general and in South Florida in particular. Quoted extensively in the "Man-made Drought" article were Dr. Patrick J. Gannon, Professor of Meteorology, Lyndon State College, Lyndonville, Vermont, Mr. Garald G. Parker of Parker and Associates, Tampa, Florida, and Mr. Arthur Marshall, retired systems ecologist and active Florida environmentalist. Dr. Gannon and Mr. Parker spoke at the conference and Mr. Marshall added his comments during the discussion sessions. Mr. Mecham was also counted among the conference.

The conference was presented in cooperation with the Coordinating Council on the Restoration of the Kissimmee River

Continued on pages 4 and 5.
Valley and Taylor Creek-Nubbin Slough Basin, the South Florida Water Management District, and the American Society of Civil Engineers. By the 8 a.m. starting time, Reitz Union employees were hunting up the extra chairs required to seat the conferees standing in the aisles and waiting in the hall. Representatives from Florida’s water management districts, the Department of Environmental Regulation, the U.S. Corps of Engineers, engineering consulting firms, public works departments, utilities, regional planning councils, agriculture, university departments of related research, industries and environmental organizations and coalitions, and the news media were in attendance, the majority of whom were still in attendance when the conference shut down at 5:30 p.m.

A synopsis of the three-part conference which brought together researchers from widely diverse backgrounds is presented below. The attached compendium were extracted from the first draft of the "Symposium Summary" prepared by Dr. Kenneth L. Echternacht, President, Southern Geotechnical Associates, Inc., Miami, Florida, Consultant to the Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin. Requests for copies of the published proceedings of this conference should be directed to Dr. Patrick McCaffrey, Director, Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin, 2600 Blair Stone Road, Tallahassee, Florida 32301 (904/488-9830).

SECTION A.
DRAINAGE AND THE HYDROLOGIC CYCLE
Moderator: James P. Heaney, Director
Florida Water Resources Research Center
University of Florida
Gainesville, Florida

(I.)
DRAINAGE IN FLORIDA
James P. Heaney, Director
Florida Water Resources Research Center
and Professor, Department of Environmental Engineering Sciences
University of Florida
Gainesville, Florida

(II.)
EVAPO-TRANSPIRATION RELATIONSHIPS
L. Hartwell Allen, Associate Professor
Department of Agronomy
University of Florida
Gainesville, Florida

(III.)
RAINFALL/RUNOFF RELATIONSHIPS
Wayne C. Huber, Professor
Department of Environmental Engineering Sciences
University of Florida
Gainesville, Florida

(IV.)
HYDROLOGIC MODEL FOR SOUTH FLORIDA WATER MANAGEMENT DISTRICT
Tom MacVicker
South Florida Water Management District
West Palm Beach, Florida
EARLY EVIDENCE OF MAN'S INFLUENCE ON THE HYDROLOGIC CYCLE IN SOUTH FLORIDA
Garald G. Parker
Parker and Associates
Tampa, Florida

REGIONAL DRAINAGE AND PRECIPITATION
Moderator: Charles L. Jordan
State Climatologist and Professor of Meteorology
Florida State University
Tallahassee, Florida

INADVERTENT PRECIPITATION MODIFICATION
Stanley A. Changnon, Director
Illinois State Water Survey
Champaign, Illinois

RAINFALL PATTERNS OVER PENINSULAR FLORIDA
Paul J. Hebert, Deputy Director
National Hurricane Center
National Oceanographic and Atmospheric Administration
Miami, Florida

RAINFALL VARIABILITY OVER PENINSULAR FLORIDA
Charles L. Jordan, State Climatologist and Professor of Meteorology
Florida State University
Tallahassee, Florida

MESO-SCALE METEOROLOGICAL MODELING IN SOUTH FLORIDA
Patrick J. Gannon, Assistant Professor
Department of Meteorology
Lyndon State College
Lyndonville, Vermont

ROLE OF WETLANDS IN RAINFALL IN SOUTH FLORIDA
Howard T. Odum, Director
Center for Wetlands
and
Graduate Research Professor, Department of Environmental Engineering Sciences
University of Florida
Gainesville, Florida

SECTION C. RESEARCH NEEDS
Panel discussion moderated by Professors Jordan and Heaney

COMPIENDIA TO SECTION A.
DRAINAGE AND THE HYDROLOGIC CYCLE

Drainage activities in south Florida started around in the late 19th century. Prior to development south Florida was 90% water/wetland and 10% range/forest; today: 50% water/wetland, 5% range/forest, 10% urban, and 35% agricultural.
The Great Florida Desert? Think about it

Fish management gets more complicated every day, mainly because we learn more and more of the problems we face. Mostly it's a case of less water and poorer water.

Drought magnifies pollution problems and another thing most fishermen don't think of — lack of sheet water. "Sheet water" refers to what evaporates and comes back as rain. What goes up is what comes down and it's mainly the shallow surface water that's taken up.

Take a wide, meandering river like the upper St. Johns or the former Kissimmee and there's plenty of water to be drawn. Channel it deep and narrow and there's a lot less to evaporate since evaporation occurs on the surface.

The St. Johns can carry off a lot of waste and has been doing it for years. High water moves it and does it fast. Drought causes the movement to be slow and the dilution to be reduced — concentrated pollution. That's the cause of our bigger fish kills in the upper river.

Extended drought in North Florida has made prairies of many lakes, a warning of more drought to come. It's more dramatic farther south where the Kissimmee River and the Everglades are taking a beating that may or may not be halted in the future.

They made a ditch of the wide and shallow Kissimmee River that runs from near the town of Kissimmee to Lake Okeechobee. The broad, vegetation-filled river of bygone years acted as a purifier for a little sewage. Now the straight-banked canal fails to handle purification of a lot of sewage. And where the surface water that once covered the Everglades used to provide heavier rainfall, now there's dusty prairie and almost constant fires.

"Perhaps the most accurate prophet of Florida's troubles is a scientist, an independent ecologist, who said recently in a Sports Illustrated interview that he notes the world's great deserts are at the same latitude as southern Florida and it worries him. The big sand pit just isn't ready for a desert image. Marshall has been around Florida's aquatic troubles for a long time and no one is more respected by conservation organizations."

A short look at a small piece of Florida can be deceiving. Take Lake Tohopekaliga near Kissimmee. Water was high there this spring and there were good fishing reports. Take a look at it and things seem great — but Toho's water level is regulated by dams and locks and this year they held water as the Fish and Game Commission asked. Good fishing. But the land to the south was drought-stricken.

And there were floods around Miami. An end to waste trouble? Not by a long shot. A temporary and deceptive oversupply of fresh water that disappears quickly and forever, the kind of thing that lulls us into false security.

The fight for water for Everglades National Park goes on. It is the brackish estuaries that supply fish for the inshore sectors of the oceans — and how far their influence goes into blue water we don't know. The Everglades National Park fishery has taken a beating and it shows plainly with redfish, snook and tarpon. New catch restrictions can help but they are not a final solution. Only more water can return things to what they once were.

The days of plentiful black bass at the heads of the national park rivers are apparently gone for good — but that loss of freshwater fish is more of an indicator than a tragedy, for few anglers fished for them.

Some of the worst signs are the lack of small fish in the brackish areas.

"We didn't catch many snook, but boy, what we got were dandies," is a common report. Bad news.

There's a shortage of the small snook that used to be thick in some of the backcountry bays and creeks. Last year we had some pretty good snook fishing, but where were the 'shorts' of less than 18 inches that we used to find in busy schools? I don't remember catching a single one. Big fish only is always a frightening sign to students of a fishery, even though they may delight the casual angler. Maybe the small fish just aren't coming at all.

There's also a shortage of small tarpon and small redfish. A 100-pound tarpon is scant comfort if you can't find any of the little fellows that used to crowd some of the holes.

Take the snook business. The mature fish spawn in the passes and the very small fish drift into the back-country shalows where they live in scant inches of water, and most fishermen, operating a little farther out, never see them. There aren't very many any more.

The big fish that show up in the passes come in from offshore reefs, from up the rivers and possibly from coasts farther south. Are they reproducing somewhere else? Are they reproducing at all? Knotty questions without answers.

Residents of North Florida often take only a casual interest in the problems farther south. It can't happen here, can it? It's already happening on a small scale as wetlands disappear over the whole state.

Bad sinkholes, dry lake beds, brackish drinking water, fish kills. The Great Florida Desert? Does this bother you at all?
(2) The average annual precipitation for the Kissimmee River Basin and south Florida is 56 inches/year. Of this 4 inches are normally due to tropical cyclones. Over the past several years there has been a 4 to 5 inch decrease in annual rainfall. This decrease could be caused by the lack of tropical storm activity over the region in recent years.

(3) In the Kissimmee River Basin and along the south shore of Lake Okeechobee the long term rainfall and runoff fluctuations alternate between wet and dry periods. There appears to be a 6 year periodicity in the records. The Everglades show similar wet and dry cycles through history.

(4) Rainfall/runoff relationships for the Kissimmee River Basin show that at least of 30 to 35 inches of rainfall per year must occur before runoff occurs. In south Florida the threshold is 35 to 40 inches/year.

(5) The ratio of runoff to rainfall increases with the increase in the percentage of impervious surface. For drained areas and deponded wetlands the runoff for a given rainfall total is greater than for undrained wetlands.

(6) Drainage affects evapotranspiration (ET) through the radiation balance, changes in the water table, changes in the vegetation, and soil moisture. For well drained areas ET is variable in response to surface dryness. For wetlands ET is nearly constant due to greater evaporation.
(7) During normal years the water table is drawn down during the dry season and is recharged during the rainy months. In periods of drought the water table can become unsaturated at lower levels such that large amounts of rainfall are then necessary to restore the table to normal levels.

(8) The present drought condition is not limited to the Kissimmee River Basin nor to the south Florida region but is present over the entire southeastern United States.

COMPENDIA TO SECTION B.
Regional Drainage and Precipitation

(1) The primary changes to climate by man's activities have been due to the burning of fossil fuels and technology related to agriculture. Man's activities generally lead to the addition of heat, moisture, and particulates to the atmosphere and to changes in the water budget via urban development, non urban industrial facilities, conversion of lands to agriculture or grazing, agricultural practices, and the creation of large lakes and other water bodies.

(2) Variation in precipitation is largely seasonal over the south Florida peninsula. Winter precipitation is mainly due to fronts such that the spatial variation is nearly uniform. Summer precipitation is due to convective showers primarily. Eighty percent (80%) of the annual total occurs during the summer and 72% of this amount occurs on undisturbed days as the result of sea breeze organization. Precipitation maxima associated with the sea breeze convergence lie in zones adjacent to but inland from the coasts. Less rain falls along the coastline and in the interior of the peninsula.

(3) Larger scale weather systems include tropical cyclones and stationary upper level systems in combination with warm/cold fronts. These systems are relatively rare but are capable of producing precipitation over the greatest spatial area and temporal duration.

(4) Drainage over south Florida presently leaves only 67% of the original surface intact; 7% is urbanized. The net result has been a reduction in ET due to

Continued on page 8.
the permanent drying of some soils, periodic drying in others, a decrease in water surface, and the increase in impervious surface due to urbanization. It has been hypothesized that the reduction in ET due to the above can lead to a potential decrease in precipitation. That hypothesis holds that the ET from the land surface in South Florida is an important source of moisture to the atmosphere over South Florida.

(5) Another school of thought is that poration from the surface over the insula contributes only a small percentage of the total atmospheric moisture over the state. It is held that the major percentage of moisture is imported into the region from the adjacent warm ocean areas.

PENDIA TO SECTION C.

Research Needs

Topic 1: This topic dealt with some

Topic 2: This discussion focused on the question regarding ET in the context what is known with respect to water body effects, measurement techniques and needed improvements.

Topic 3: The question was posed as to how one determines what changes, if any, have occurred in the climate of South Florida. Can changes be documented from existing data? The need is to statistically document what has happened.

Topic 4: The question of spatial resolution in meso-scale modeling was discussed.

Topic 5: Is ET decrease that important or does it merely correspond to a 5% decrease in the rainfall? It was suggested that over South Florida ET serves to increase mass convergence and thereby acts as a trigger mechanism to increase convection.

Topic 6: The economic impact of a decrease in precipitation was discussed.

** ** **
Somebody did something about the weather in Florida; now a looming disaster demands that it be undone

by ROBERT H. BOYLE and ROSE MARY MECEM

SPECIAL REPORT

Over the past few weeks, a growing number of Floridians have been jolted by a warning from Arthur Marshall, a 63-year-old ecologist who is widely regarded as having the keenest insights into that state's multiple environmental problems. Marshall's dismaying thesis is this: Drought conditions in Kissimmee Valley, which suffered a "once in every 700 years drought" last year, are going to get worse. Marshall asserts that last year was not in fact a meteorological aberration, but a predictable consequence of the land development and the drainage of wetlands in the Everglades and the Kissimmee River basin that have disrupted the normal rain cycle.

The gist of the problem, says Marshall, is this: Before development changed the South Florida landscape on a huge scale, the slowly moving sheet of water that annually flowed from the Kissimmee River basin south into Lake Okeechobee and then spilled into the Everglades was the key to the region's abundant rainfall. During the rainy season, which runs from June into September, the summer sun would heat up this shallow sheet water to approximately 14°C above its nighttime temperature, and tremendous amounts of water would ascend into the atmosphere by evaporation and transpiration from the lush plant life growing in the marshy environment. By two in the afternoon, the buildup in the atmosphere was so great that heavy rain would fall. Almost all the water that had risen from the wetlands would come down again, and with it rain from vapor that had moved in over the peninsula from both

Anatomy Of
A Man-made
Drought

continued
Marshall's thesis is taken very seriously by scientists who have independently investigated aspects of it in their own research, some of which Marshall has drawn upon to arrive at his overall conclusions. "That's a very true picture," says Gerald G. Parker of Tampa, who explored and named both the Biscayne and Floridan aquifers while he was with the U.S. Geological Survey and who later served as the chief hydrologist with the Southwest Florida Water Management District. "Man-made alterations and drainage on this scale have certainly accomplished these results. The Gulf Coast is affected, too. It is a serious situation." Patrick Cannon, a meteorologist who wrote a doctoral dissertation at the University of Miami entitled "The Influence of Surface Properties and Clouds on the South Florida Sea Breeze," says, "We have introduced significant changes in the daily mesoscale weather patterns in the last century. This entire cycle has been altered, weakened and shifted. It's radically different now that it was in 1900, and it appears from all the research that we're setting up a heat regime rather than a rainy regime in the summer period."

It finally rained heavily in South Florida last week, but the three to four inches that fell in the interior were literally a drop in the bucket in a region where one-sixth of an inch of water evaporates into the air every day. Cannon attributes last week's rain to a cold front coming down from the north, a synoptic (large-scale) disturbance. "The basic problem is in the region's long-term summer rainfall mesoscale process," he says. "South Florida is going to be faced with a long-term drought potential that is only temporarily alleviated by transitory synoptic disturbances, such as deep mid-latitude troughs in the Gulf of Mexico and tropical storms."

Last week, state politicians were paying heed to Marshall's thesis. State Senator John Vogt, chairman of his chamber's Natural Resources Committee, had breakfast one morning in Tallahassee with a party that included Johnny Jones, executive director of the 45,000-member Florida Wildlife Federation and a close associate of Marshall's, who is a director-at-large for the F.W.F. Jones was in Tallahassee pushing for restoration of the Kissimmee River and its floodplain. Six years ago, he had successfully lobbied through a bill calling for just that. Before the once-meandering river was turned into an aquatic highway by the state and the U.S. Army Corps of Engineers in the late 1950s, the Kissimmee played host to one million waterfowl a year. "After channelization, we counted just eight ducks," says Jones. "Eight, as in one, two, three, four, five, six, seven, eight!" Channelization also ruined the superb largemouth bass and bream fishing, and with the wetlands gone, pasturing cattle took to the river to cool off in the summer heat. "A cow doesn't get out of the water to take a crap," Jones says, "and just one of them puts out wastes equal to 18 people."

Although Senator Vogt was aware of the rain-machine thesis, Jones went over it briefly at breakfast and then pointed out to the senator that last year only 71,000 acre-feet of water had passed through the channelized river into Lake Okeechobee, as compared with an average annual inflow of 1.2 million acre-feet from 1935 to 1950. Lake Okeechobee, which encompasses 730 square miles, is the surface storage basin for South Florida's water. It is now three feet lower than it was at this time last year, and last year is acknowledged as the worst in recent history. Jones also told Vogt that annual rainfall in St. Lucie County in southeast Florida had declined from 68 inches in 1950 to 38 inches following the draining of more than 50,000 acres of wetlands.

Although the 1976 bill authorizing restoration of the Kissimmee River basin had passed, nothing had been done because the Corps was, in Jones's words, "dragging its feet." Jones asked Vogt, "John, if the feds don't get off their butts, will you initiate legislation using state funds from the Conservation and Recreation Lands bill and the Save Our Rivers bill to start filling that ditch?"

Vogt said he would. "Florida just can't support unlimited development and drainage of wetlands," the senator said. "What frightens me is that all the great deserts of the world lie at this latitude. I just hope Florida won't become a desert." (One development that need not frighten Vogt is the new TPC golf course described on the preceding pages. Marshall, who has visited the course, says the land has been used with the ecological health of the area in mind.)

That afternoon Jones conferred with Governor Bob Graham, briefing him on Marshall's findings. In that meeting Gra-
ham reaffirmed his support for restoration of the Kissimmee. "The old Bob Graham is returning," Jones said afterward. "He was an outstanding conservation senator. When he became governor, he appeared to have lost interest in the environment, but in the last year he has taken the leadership role on issues like the Kissimmee. We appreciate that."

The next day Jones, Marshall and Nat Reed drove to Clewiston on the south shore of Lake Okeechobee to discuss restoration of the Kissimmee with John B. Boy, the president of U.S. Sugar Corp., and Dalton Yancey, general manager of the Florida Sugar Cane League. Environmentalists and sugar growers have often gone head-to-head on issues, but, as Jones put it, they were all in the same boat now because of the drought, and he wanted their support for restoration of the Kissimmee. Last year Florida surpassed Hawaii as the No. 1 state in sugar production, with more than a million tons. Based almost exclusively in southern Florida, the sugar industry farms 349,000 acres of black muck that was formed by 5,000 years of decaying wetlands vegetation. If this muck doesn’t get an abundant supply of water it dries out like talcum powder and burns when touched with a match. Last fall drought conditions were so bad, the fearful growers drew on this spring’s allotment of water from the South Florida Water Management District in order to be able to plant the current crop. They had to gamble in doing that, because they might have lost not only the crop but also their soil to fire. Now, there is fear of reduced yields this year because the growers will have to depend almost solely on rain; the allotment of water left for them in Lake Okeechobee is not enough to meet the growers’ irrigation needs.

After the meeting, Boy and Yancey remained committed to restoration of the Kissimmee, but Jones has hopes that the growers at least won’t oppose it. Boy and Yancey were also skeptical about Marshall’s rain-machine thesis, but as Marshall said, "If I were the president of U.S. Sugar, I’d sure as hell wonder why none of my scientists had told me about the importance of the Kissimmee River basin to rain in South Florida. The crop depends on rain, whether it falls on the land or comes from Lake Okeechobee as irrigation water."

Marshall’s deep involvement with the Florida environment began in 1960 when he became the state administrator for the U.S. Fish and Wildlife Service. He left Fish and Wildlife in 1970 to devote his time to the study of Florida ecosystems. He was a professor at the University of Miami and later at the University of Florida before becoming a private consultant in 1974. Systems is the key word for Marshall. "If you don’t synthesize knowledge, scientific journals become spare-parts catalogues for machines that are never built," he says. "Until isolated and separated pieces of information are assimilated by the human mind, we will continue to rattle around aimlessly. I am as good a diagnostician of ecosystems as any good medical diagnostician is of human beings, and I’m not on any damn ego trip when I say that. I read medical journals to see how medical diagnosticians work. Sometimes I wish I didn’t have the knowledge that I do, because I can get pretty damn glum."

To Marshall, the Kissimmee lakes near Orlando, the lower Kissimmee River, Lake Okeechobee and the Everglades are all a single system. "Not enough people realize it’s all of a piece," he says. "I didn’t invent the whole system. I was able to observe it long enough to understand its processes and to recognize how they work together, the sheet flow, the muck, wetlands vegetation, recharge of the Biscayne Aquifer and the production of marine fisheries. The only source of water is rainfall, and it only comes in a four-to-five-month period. You have to extend the life of that water. That’s what the system did originally. It was one of the most efficient systems you could imagine on the face of the earth. Now we have to repair it."

According to Marshall, the upper Kissimmee lakes are in trouble. Lake Tohopekaliga receives 20 million gallons a day of treated sewage effluent, and its sport fishery is headed for collapse. To an extent, this lake has acted as a buffer for the lower lakes, but this cannot continue indefinitely. Already Lake Okeechobee is becoming oxygen deficient. South of the lake, agriculture is in obvious trouble, as is the Biscayne Aquifer. Last year the South Florida Water Management District had to pump 325,000 acre-feet of water from the lake into the coastal canals to fend off saltwater intrusion. A soon-to-be-published paper by Jim Kushlan of the Everglades National Park staff discloses that the population of freshwater wading birds in the park has declined by at least 90% over the past 40 years, with decreased water flow and loss of wetlands playing critical roles. Chief hydrologist Dr. Peter Rosendahl reports that the park will shortly make a request to the South Florida Water Management District and the Corps for an additional 450,000 acre-feet of water, more than double what the park has been getting annually.
Florida Bay and the Ten Thousand Islands area to the northwest are suffering greatly. "Fifty species of marine fish and shellfish utilize the shallow water of the lower Everglades," Marshall says. "The hatching is timed to coincide with the start of the rainy season in June. The snook hatch in the new moon in June, and that's it. The snook is a classic case of dependency on the sheet flow. They spawn in the saltwater passes in the Ten Thousand Islands area. After the eggs hatch, the larvae move up toward fresh water, and they're always in the top half inch of the water column. They go into the shallow sheet-flow water and stay in the Everglades through the winter and feed. There used to be plenty of food supply delivered to them by the sheet flow. It was such a natural time clock. Then in the spring, when the snook were five or six inches long, they would come back down. But now that's all changed. We have cut the shallow-water acreage in the Everglades in half, and we have also cut the time in half. Instead of the juvenile snook having nine to 11 months in sheet flow, it is down to four or five months.

"During World War II," Marshall continues, "the state allowed commercial fishermen to use huge seines for snook, and in one set of a net they could get up to 5,000 fish, averaging two pounds apiece. About six weeks ago, I went over to the Department of Natural Resources marine lab in St. Pete to see Dr. Gerard Bruger, who has done six years of tagging studies of snook, and he told me that the total adult population of snook in the Ten Thousand Islands area is only about 30,000. That ain't nothin'! Bruger calls the snook an endangered species."

Last December, guides from Islamorada in the Keys and fishermen working with the American League of Anglers, a national organization of sports fishermen, conducted a semiscientific study by fishing Florida Bay intensively. The bay was once one of the most productive bodies of water in the world, but a follow-up report by the A.L.A. stated that the 810-square-mile bay has been hit so hard "that it's a question of whether or not it can ever be restored." There were few redfish, sea trout were even scarcer, and no bonefish at all were caught. The A.L.A. also noted that commercial catches of silver mullet had declined precipitously, dropping from just under 2.5 million pounds in 1975 to less than 188,000 pounds in 1980.

Marshall believes that the fishing can be restored in Florida Bay, but radical change will be required, beginning with restoration of the floodplain of the Kissimmee. Basic to all South Florida, he says, is the reinitiation of the "rain machine." Despite backing from many scientists, Marshall is well aware that his thesis has critics, including Jack Maloy, the executive director of the South Florida Water Management District, and Dr. Patrick McCaffrey, staff director of the Kissimmee Coordinating Council. In fact, Marshall takes heart from the criticism. "I was ridiculed so many times in the past when I turned out to be right. I've gotten to the point where if I don't get ridiculed, I wonder if I'm doing something wrong," he says.

Even though Marshall had put together the South Florida ecosystem in his mind 10 years ago, he didn't realize the full significance of the rain machine until last year, when he found a copy of an out-of-print report, Water Resources of Southeastern Florida, written by Parker and other hydrologists and published in 1955 by the U.S. Geological Survey. Marshall began comparing data from it with other studies, including Gannon's dissertation and a 1972 report by a planning engineer at the South Florida Water Management District, on whose board Marshall served in 1972 and '73. Last Jan. 12 in Palm Beach, Marshall gave a speech on his findings at a symposium on the Everglades, and two weeks later he had a meeting with Governor Graham.

Parker and Gannon are all for the restoration of the Kissimmee, but Gannon, who spent eight years as a meteorologist with a federal task force doing research on cloud seeding before becoming a professor at Lyndon State College in Vermont last year, points out that the rain machine of South Florida has been permanently impaired in part by "the capping of both coasts with concrete at the same time the Kissimmee was going down the tube," which retards the evapo-transpiration process.

If Gannon had it within his power, he would put an immediate stop to development. For instance, he would refool Golden Gate Estates, a huge tract of land east of Naples that was drained but never built on. "To call for cloud seeding or water conservation is not the same as doing all-out research on the causes or potential causes of the problem," Gannon says. "The most reliable and sensible way to demonstrate the effect of surface alterations is through numerical modeling. You can't observe rainfall in 1900, but you can numerically simulate 1900, the present time and what is likely to happen in the year 2000 or 2030 at the present rate of land alteration." Gannon believes that it is important that Florida do this so the public can realize what has been happening to the state.

Marshall agrees. The vitality of the state is at stake, and as Jones says, "Art Marshall is more than an ecologist. He's a prophet. He has been right every time when he has called the shots. The South Florida Management District has been light-years behind him in knowledge and understanding of the system. If Marshall had been right once, I might not have the faith I have in him, but he has been right, right, right, and the people and politicians had damn well better listen to what he says."
Drought Blamed on '60s Drainage Project

By Jeffry Kahn
Post Staff Writer

Florida is suffering from a man-made drought, ecologists and researchers have charged.

Disputing the South Florida Water Management District's contention that the area is gripped by a climatic aberration which happens only once in 700 years, ecologists say a 1960s project which drained the Kissimmee River Valley has catalyzed a drought that will recur.

WMD Executive Director Jack Maloy said it's possible that drainage of the valley may have contributed to the drought. He's ordered his scientific staff to study new indications that man might have permanently altered valley rainfall patterns.

Chief proponents of the man-made drought theory are Art Marshall, the ecologist-guru of many Florida environmentalists, and Johnny Jones, executive director of the Florida Wildlife Federation.

Their contentions, widely reported in Florida and widely discounted by state officials, is receiving national attention. Sports Illustrated magazine, in its March 15 issue, details their warnings in a special report entitled, "Anatomy of a Man-made Drought."

Like the WMD, Marshall and Jones see the Kissimmee lakes below Orlando, the Kissimmee River, Lake Okeechobee and the Everglades as a single, integrated hydrologic system. Rains fall in the 3,000 square-mile Kissimmee Basin and run down the channelized river into Lake Okeechobee which used to provide a sheetflow of water for the Everglades region to the south.

Like the WMD, Marshall and Jones see a dramatic decrease in rainfall in the Kissimmee Valley over the past decades. Unlike the WMD, however, Marshall and Jones believe this critical loss of rainfall is almost entirely attributable to a 1960s public works project that channelized the Kissimmee River and drained the valley.

"We drained the rain machine," Jones said.

"The Kissimmee Valley was the rain machine that supplied water to Lake Okeechobee. Without that, the lake is a crippled reservoir that is on the verge of collapse. That's exactly what is happening right now . . . "

Unlike the WMD, Marshall and Jones believe the critical loss of rainfall is almost entirely attributable to a 1960s public work project that channelized the Kissimmee River and drained the valley. "We drained the rain machine," Jones said.

'Because the Kissimmee was the rain machine that supplied water to Lake Okeechobee. Without that, the lake is a crippled reservoir that is on the verge of collapse. That's exactly what is happening right now . . . '

The Kissimmee Valley used to be a very wet area receiving around 50-55 inches of rainfall a year. The Kissimmee soils were saturated most of the year, at times inundated and often flooded. Because of that, the cattlemen who owned most of the valley wanted these wet prairies dried up to increase their available pasturage," Parker said.

During the 1960s, he said, the meandering river was straightened and channelized so as to drain the wet prairies.

"In doing that," Parker said, "the water levels fell several feet below the land surface. This greatly decreased the evaporation and transpiration.

"This water loss resulted in a decrease of water vapor which formerly was carried up into higher levels of the atmosphere where it became colder, formed clouds and fell back to the ground as rain. That cycle has been disrupted by the ditching and draining of the Kissimmee Valley."

Prior to the ditching, Parker said, the weather patterns were different.

"It used to be when I worked there in the valley in the 1940s, you could count on rain every afternoon between 2 and 4 p.m. That doesn't happen regularly any more.

"There isn't the local source of water vapor that formerly existed there. Of course, the drainage of the Kissimmee is a

"Turn to Drought, B3"
factor in the drought. Unless the (Army) Corps (of Engineers) gets back in and restores the damage, we will have diminished rainfall,” Parker said.

In 1976, the state Legislature asked the Corps to restudy what it had done to the Kissimmee. Since, sentiment has changed among most state officials including Gov. Bob Graham for some form of repair to the valley. The Corps, however, has yet to complete its study.

Feb. 11, the state put its foot down. Department of Environmental Regulation officials, who wrote the Corps’ district engineer Col. Alfred Devereaux compelling him to “expedite the Kissimmee River survey review.”

Ms. Tschinkel gave Devereaux a deadline of Sept. 24. By then, she wrote, the Corps should lay out its recommendations for review by the state’s Kissimmee River Coordinating Council. The council, in turn, will report to the governor and cabinet.

Graham has yet to indicate which form of repair he favors, saying only that he wants the “positive functions” of the river restored. According to Graham aide Estus Whitfield, these include the river’s water storage capabilities, the watersheds it provides for fish and wildlife and its capacity to clean water. Water fowl, once abundant in the valley, have all but disappeared.

Jones predicts Graham will opt for partial reflooding of the valley.

“Partial backfilling is the way to go. It’s the only alternative that the environmental community will accept. Other alternatives being reviewed by the Corps amount to a barrier or dike. These amount to not doing a damn thing but snowing the people,” Jones said.

Some 40,000 acres, Jones said, must be reflooded at a cost of about $40 million. Jones said the state is quietly moving to acquire these lands before the Corps concludes its study of how to repair the area. The WMD has identified 18,000 acres in the valley which are being considered for acquisition.

WMD Executive Director Jack Maloy said he believes new questions have been raised by Dr. Patrick Gannon, a meteorologist quoted in the Sports Illustrated story.

Gannon wrote a doctoral dissertation at the University of Miami entitled “The Influence of Surface Properties and Clouds on the South Florida Sea Breeze.”

“Ve have introduced significant changes in the daily mesoscale (local weather patterns) in the last century. This entire cycle has been altered, weakened and shifted. It’s radically different now than it was in 1900 and it appears from all the records that we’re setting up a heat regime rather than a rainy regime in the summer period . . .

“South Florida is going to be faced with a long term drought potential that is only temporarily alleviated by transient synoptic disturbances (large scale weather systems like cold fronts moving in from the north) such as hurricanes tugging at latitude from the Gulf of Mexico and tropical storms,” Gannon told Sports Illustrated.

The critical question raised by Gannon, Maloy said, is whether the water table in the Kissimmee Valley has been reduced. That is unknown but must be determined, he said.

Gannon said development should be halted in Florida.

“To call for cloud seeding or water conservation is not the same as doing all-out research on the causes or potential causes of the problem,” he told the magazine. He urged that research centers design a weather model that can predict the climatic effects of continued surface alteration and development in Florida.

Maloy, who manages the water system from the Kissimmee Valley to Lake Okeechobee to the Everglades, is as accorid as saying water managers no longer have unlimited amounts of water to dole out to new water users. The computer models described by Gannon would be useful and the WMD may design such a model, he said.

While noncommittal about what has happened in the Kissimmee Valley, Maloy does not believe the Kissimmee is the total cause of the drought.

“The thing that disturbs me a little is you get the impression the entire drought was caused by the channelization of the Kissimmee. If that’s so, what caused the dry conditions in South Georgia? What was this one of the few recent times that low water caused a stop of navigation on the Apalachicola River? Why was the Suwanee River so low? . . . The whole southeastern U.S. had a rainfall deficiency last summer,” Maloy said.

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Who Knows The Rain?

Nature and Origin of Rainfall in South Florida

by
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Jessie Freeling
Leonard J. Greenfield, Ph.D.
Patrick T. Gannon, Sr., Ph.D.
Published by
The Friends of the Everglades
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FOREWORD

Frontispiece — The rain god Tlaloc, the oldest and most persistent of the gods of Mesoamerica.
The alarming crisis in the fresh water supply of south Florida is at last being recognized by the general public. We are being forced to realize that Lake Okeechobee, our natural reservoir, is no longer capable of supplying the volume of water absolutely necessary to the tremendous increase in population in this region, to industry, to agriculture, the groves, the plant life, Everglades National Park, and indeed to keep the Everglades wet enough so that the whole area will not burn down to the underlying rock.

The modern system which has permitted this dangerous situation to develop was begun in 1947 when the control of floods in the Everglades was turned over to the U.S. Army Corps of Engineers supported by the politically appointed Central and South Florida Flood Control District (CSF-FCD). Since the emphasis of both bodies was on flood control, little consideration was given to the conservation of fresh water. The result was that by the Corps' complex system of dams, pumps, and increasing number of drainage canals, the level of Lake Okeechobee and the water table in the agricultural areas were kept low by the runoff of billions of gallons of fresh water into the Gulf of Mexico and the Atlantic.

Since 1947, the population of south Florida, both in city and county areas, increased enormously, even as the supply of fresh water was diminishing. This dangerous situation was recognized in 1972 by the passage of the Water Management Act which divided the state into five water management areas each directed by its own district board. The name of CSF-FCD was changed to the South Florida Water Management District (SFWMD) but with the same complete powers over water control and no improvement in the policy of water conservation.

In 1969, the Corps of Engineers, at the request of the old CSF-FCD, completed the system of canalyzing the Kissimmee River, replacing its
ancient meanders through swampland by a straight canal to Lake Okeechobee. The Lake at this writing is at its lowest level in history. This is not entirely due to the rainfall situation in south Florida. Since Lake Okeechobee had been supplied by fresh water from the Kissimmee River, the canal curtailed the supply of water to the lake. Water overflowing south of the lake into the Everglades was therefore also curtailed. The entire system of the Kissimmee-Okeechobee-Everglades basin, by artificial means, is thus less able than previously to deliver adequate water to the now crowded region. Because of the excessive drainage, salt water has penetrated up the drainage canals to Everglades land so that the Control District has had to let out many gallons of fresh water to provide a hydrostatic head to keep the salt water in check.

One reason for the inadequacy of the system has been a general ignorance of the nature and origin of our fresh water. The Environmental Protection Agency declared two years ago that the sole source of fresh water in south Florida is rainfall, but rainfall here seems never to have been understood either by the officials who managed the fresh water system or the general public. Now that the rains are inadequate and the lake is at its lowest recorded level of 9 feet, the District, which is almost helpless, is contemplating the complex process of cloud seeding. We shall show in the article by Drs. Gannon and Greenfield that rainfall to the Everglades is to a great extent influenced by drainage practices and other artificial changes in the area.

This small book is therefore the first attempt to make clear to the general readers the true nature of our all-important rainfall. The Friends of the Everglades are proud to present it as Number One in our contemplated South Florida Regional Study Series.

We are highly indebted to the small distinguished group of scientists and environmentalists who have written the essays included here. Mr. Leonard G. Pardue, a certified meteorologist and specialist in Florida weather since 1943, is widely known for many years as a member of the U.S. Weather Bureau in Miami and as the comforting radio voice in the stress of many a hurricane. In retirement from that post, he was a helpful director of the Dade County Science Museum and is currently a
consulting meteorologist. No one better than Mr. Pardue can present the picture of our normal rainfall.

Jessie Freeling, who for some years has been the Hendry and Glades County Chairman of the Friends of the Everglades, was born in Miami and educated at Florida Southern College. She has spent much of her life on intimate study of the geography, botany, and zoology of this area. It was her tireless observation and recording of the effects of rainfall on vegetation which provided the unique material of her paper on wet and dry cycles, the value of which was recognized by the scientists associated with this work.

Dr. Patrick T. Gannon, Sr., Ph.D. was for some years a distinguished meteorologist with the National Hurricane and Experimental Meteorological Laboratory of NOAA in Coral Gables, Florida. He has studied and written much about wetlands and their effects on local climate. Currently, he is involved in the modeling of mesoscale rainfall situations at the NOAA research facility in Boulder, Colorado.

Dr. Leonard J. Greenfield, Ph.D., was for several years at the University of Miami at the Rosenstiel Institute of Marine and Atmospheric Sciences and was later Chairman of the Biology Department of the University where he taught and did research on wetlands ecology and water chemistry. He is currently a researcher and consultant for Rio Palenque Research Corporation and serves on the Science Advisory Board of EPA. We are greatly indebted to Dr. Greenfield not only for his work in collaboration with Dr. Gannon but also for his interest, enthusiasm, and hard work as an editor, which made this book possible.

Marjory Stoneman Douglas.
July, 1981
Figure 1 — Map of south Florida showing pertinent latitudes and longitudes and proximity to the Tropical Zone.
INTRODUCTION

Some 6—8000 years ago, the major civilizations that we know emerged. Their occurrence was directly related to the domestication of crops needed to support growing populations. Likewise, crop domestication meant the control of water resources as the single most important resource available to the grower. It took a long time to get to the productive stage—perhaps up to about 4000 years prior to the above-mentioned period.

The word 'control' means not only the use of water conservation measures and irrigation, but also the knowledge of where the water comes from and when it will come. Sometimes predictive measures in ancient times seemed workable, but understanding them remained obscure to most people. For instance, the Egyptian farmer knew that when the Dog Star reached its highest point in the sky, the Nile would rise; and the head of the Mayan cooperative knew that when the Trade Winds bent certain reeds to a particular angle, it was time to plow the ground. But there were other individuals whose specific job it was to try to comprehend the water cycle, the wet and dry season, the coming of the rains. Their scientific approach to those problems turned folklore events into a refined technology that resulted in: the Meso-American and South American metropolises and the culture of corn, potatoes, beans, and cotton; the blossoming of the Fertile Crescent around the Tigris and Euphrates Rivers in Mesopotamia and the introduction of cereal grains; the glory of the Nile Valley and its barley and millet; the burgeoning of the populations in the Indus Valley with its wheat fields; and the very ancient Chinese civilization and its use of the great rivers for rice growth.

During those times, interest in the weather and the rain that it brought was shared by everyone, and political power was based to a large extent upon water rights. It is most intriguing that in the areas
where these civilizations arose, the interests of the ruling politicians changed, and the civilizations toppled. The farmers in those areas, however, still maintain, defend, and hold political sway over riparian rights to their land. They remain today, as they once did, the basic productive individuals in their respective communities.

In our present era, we are well aware of the essential aspects of water-use for farming, daily consumption, and beyond. Those of us who live in south Florida have further been made aware of the fact that we live in a wetland. This wetland not only provides us with our daily water requirement for survival, but also controls the kind of unique environment that is south Florida. In one sense our attempt here is to revive the general interest in our wetland environment. Therefore, it is important that we understand the factors directly involved with it. One of these factors is the weather, since it is the rain that remains, as always, our primary water source.

We will approach the problem of understanding our weather by first briefly discussing general aspects of weather and climate. Then we focus our attention on south Florida and its particular climate dynamics. One very critical problem in south Florida is the rainfall cycle, how it varies, and whether or not it is predictable. This will be discussed in detail—particularly with regard to its replenishment of our ground water. The latter, we will see, may be a mechanism in long range prediction of the rainfall cycle.

Having converged on the issue of water resources in south Florida, we can then analyze the effects and influences of human activity on local weather conditions. It is the result of recent findings that gives us the data allowing us to do this.

No great attempt is made here to analyze the complex science of Meteorology. Neither is there the desire to duplicate recent works which discuss the water and wetlands ecology of south Florida. Rather, the objectives are to explain those fundamental technical aspects that refer to our regional situation and to dwell upon those deemed important and which have not yet been confronted sufficiently.
GENERAL ASPECTS OF WEATHER AND CLIMATE

Leonard Pardue

One of the earliest writers about the weather was Aristotle more than 2000 years ago. Much of his material consisted of weather signs, superstitions and lore; and, as in most other scientific fields, Aristotle’s word was taken as law for many years. It was only after weather-measuring instruments were invented in the 17th century that any advancement was possible.

Along with new information came a new technical terminology of weather conditions and instrumentation. Before we can determine what the effects of weather are on us in south Florida, it will be necessary to understand some of this terminology about the weather—especially that which will concern us.

To begin with, weather can be defined as the state of the atmosphere at any given time. The principal measurable or readily observable aspects of the weather include the state of the sky, whether sunny, cloudy, or raining; temperature of the air; the wind speed and direction; the moisture content or relative humidity of the atmosphere; and the barometric pressure.

If the weather measurements are recorded and analyzed for a long time and averaged periodically (monthly, yearly, etc.), the resulting averages are regarded as ‘climate’. A thirty-year period is regarded by climatologists as a bare minimum time of measurement for adequate conclusions to be made about climate. A much longer period is required if one is to search for meaningful changes.
With the invention of the telegraph early in the 19th century, it became possible to collect weather observations made at the same hour at various locations over large areas and to construct weather maps, which came to be known as 'synoptic'—meaning maps that gave a broad-scale simultaneous picture. As more and more international exchange of weather data became possible, the scientists drew hemispheric maps showing, as nearly as they were able, the weather 'picture' north of the Equator. Subsequently, the construction of world-wide maps became feasible as more information from the Southern Hemisphere became available. Actually, it was not until the early 1940s that wartime needs for weather data resulted in the formation of a satisfactory weather-reporting network.

The reportorial advantage of data accumulation has led to certain terminology refinements whereby weather phenomena can conveniently be classified according to the size of the area it influences or 'scale'. 'Microscale' can be used to identify weather occurrences that might be the size of a small town. 'Mesoscale' (from 'meso' meaning 'middle') can be used to categorize happenings from the size of a county to the size of an average state, like Florida. The 'synoptic' scale, also called 'cyclonic', characterizes highs and lows on the weather map, typically from 300 to perhaps 3000 miles across. Beyond that size, weather events are called 'planetary' or 'macroscale', i.e., anywhere from the size of the oceans upward. The mathematics used in calculations of weather systems can also be scaled to fit the problem so that the numbers encountered will not become unmanageably large or small.

The fundamental measurements employed in weather analyses just referred to include barometric pressure, wind, temperature, and the moisture content of the air. The Italian physicist, Torricelli, invented the first crude barometer in 1643; Galileo preceded him with the invention of the thermometer and probably with the wind vane. The Beaufort Wind Scale, devised by Admiral Francis Beaufort of the British Navy about 1805 and still in use, evaluated the wind speed by its effect on sailing vessels. It later was modified for use on land.

The widespread use and collection of base-level meteorological in-
formation demonstrated the need for a central organization of control and distribution, especially one that is accepted internationally. The World Meteorological Organization (WMO), an arm of the United Nations, coordinates international exchange of weather reports. WMO long ago specified the hours for the exchange of meteorological observations as Midnight, 6 AM, Noon, and 6 PM, Greenwich Time—known as 'Z' time in the trade. These hours correspond respectively to 7 PM, 1:00 AM, and so on, EST. Readings are taken in various countries at other hours as well—depending upon local need.

The reports are exchanged by radio and landline so that each forecast center, for example the National Hurricane Center at Miami (NHC), has a complete weather map plotted within about an hour and a half after the standard collection times. (NHC is not only a hurricane forecast center; it also does general and aviation forecasting for a considerable land and marine area adjacent to Florida.)

After the local or regional reports are plotted, the analysts locate the cold and warm fronts on a large map the size of a card table, then draw lines through points of equal barometric pressure, resulting in a weather map somewhat like those in the newspapers and on television weather shows.

Simultaneously at the National Meteorological Center (NMC) near Washington, D.C., a highly skilled group of analysts makes an intensive study around the clock of weather patterns on the synoptic scale upward through the planetary scale. In the latter procedure, a vast complex of computers has proved indispensable. These machines, with a prodigious memory, can be directed to analyze the atmospheric pattern in any one of a dozen or more ways. Thus, broad-scale weather patterns are analyzed, from which forecasts on a grand scale are possible.

It must be realized, however, that any computer is capable of doing only what it is told to do. Put another way, a team of analysts could accomplish the same task by hand, given enough time.

The first organized effort to investigate the preparation of a weather forecast by mathematical means took place in the early 1920s by a
British meteorologist, L.F. Richardson, who led a team of investigators using desk-top, hand-cranked calculators. This was strictly an experimental procedure, to determine if we knew enough about the atmosphere to make a meaningful objective forecast.

The answer was a resounding 'no'! The forecast, which took weeks or months to prepare, was so wide of the mark that mechanical forecasting was set back for a generation, to await a better theoretical base, faster computers, and a denser network of weather reports.

Students of weather prediction then are led to a logical question: Why cannot the forecasters crank up their computers and develop a perfect forecast if given enough past history? The reasons are many and highly involved.

First, although the mathematics used in computer operations can be organized to simulate almost any situation, the dynamics of the atmosphere are so complicated that so far no one has been able to formulate a complete mathematical description of weather patterns. Second, instead of proceeding directly to a forecast using a few data points, it is necessary to take very many data points extrapolated continuously, in increments of five minutes for instance. And, instead of using only weather measurements the computer uses many derived readings spaced regularly some miles apart in both directions on the weather map. They are able to do this by taking some measurements of a few factors and calculating what the values would be a reasonable distance away.

This process is capable of good results in many cases. There are exceptions, however; for instance, in a rapidly changing severe-weather situation, which is to say, a situation in which a correct forecast is highly important, the computer-made product is apt to stray from reality after a relatively few steps. It is then necessary for a skilled analyst to substitute his or her judgment and experience in place of the objective process that led to the computer product.

A weather model is a theoretical description of the way the forecasters believe the weather will act. A number of theoretical models have been tested, each having faults and advantages, each advancing the
level of research further. In any event, the model of the atmosphere must be such that a computer can utilize the mathematics with which it is presented. The memory capacity required for the computations is unbelievably great. Not only must the grid points be placed closer and closer together in the improved models, but also a greater number of altitude levels in the atmosphere above the surface of the earth must be constructed—as many as twelve having been used. The theory must be developed completely and then adjusted or modified so that it can be computer processed.

SUMMARY

1. Weather is the state of the atmosphere at any given time (state of the sky, air temperature, wind speed and direction, humidity, and barometric pressure).

2. Weather measurements averaged over a long period of time (minimum of thirty years) are regarded as ‘climate’.

3. Size of the area influenced by weather or ‘scale’.
   - Microscale = weather occurrences the size of a small town
   - Mesoscale = from county to average state size (e.g. Florida)
   - Synoptic = highs and lows on the weather map; can be 300 to 3000 miles across. Also called ‘cyclonic’.
   - Macroscale = anywhere from the size of oceans and greater. Also called ‘global’ or ‘planetary’.

4. The World Meteorological Organization (WMO) of the United Nations coordinates international exchange of weather reports. The National Meteorological Center (NMC) near Washington, D.C. coordinates planetary through synoptic scale data. The National Hurricane Center (NHC) covers mesoscale to synoptic level data.

5. A weather model is a theoretical description of the way the forecasters believe the weather will act.
CLIMATE OF FLORIDA AND SOUTH FLORIDA

Leonard Pardue

How do these esoteric processes relate to the weather and climate of a known area such as Florida? Our state commences just north of the Tropic of Cancer, between Havana and Key West, at latitude 24° 33'. Several Florida counties share the northernmost boundary at 31°. The state extends from slightly west of 80° west longitude, near Lake Worth, to 87° 38', between Pensacola and Mobile. The coastline extends more than a thousand miles—the greatest of any of the contiguous states.

These factors, i.e., the low latitude and the nearness of the ocean and the Gulf of Mexico, account for the state’s subtropical-marine climate. The subtropical aspect is denoted by the fact that many tropical plants can reach maturity between the infrequent hard freezes that occur over the southern portion; e.g., the Coconut Palm is found northward to about Palm Beach and Fort Myers. The maritime quality of the climate is exhibited by the damp, warm summers, infrequent tropical cyclones, and the moderate winters, which are occasionally interrupted by the incursion of colder, drier air from more northern latitudes.

One of the features of Florida’s climate is the prevailing wind direction. South of about latitude 28°, the state experiences easterly winds virtually all summer and perhaps half the time in winter. North of 28°, the winds are more likely to be westerly both in summer and in winter. Thus tropical air masses, i.e., air masses that come from warmer regions, are the rule all summer and half the winter, subject to exceptions when winters turn out to be uncommonly cold.
The Florida rainfall pattern is roughly uniform over the southern half of the state, i.e., below 28° latitude, with wet summers and relatively dry winters. At Miami, about 75% of the year’s rainfall comes during the so-called rainy season, late May through late October. At Orlando, the rainy season percentage is a little less, while at Tallahassee, the rainfall is more evenly distributed from season to season. At Miami, the wettest month, September, has, on the average, 5.67 times as much rain as the driest month, December. At Orlando, the ratio is 5.10 times and at Tallahassee, with the different distribution pattern, it is only 3.31 times. The lower this ratio, the more uniform is the rainfall from month to month.

As mentioned, the wettest month in Miami is September, and the second wettest is June, while the driest is December. At Orlando, the rainfall from July through September is roughly the same each month, with December the driest. In the Panhandle, July is wettest, March has a secondary peak, and the driest month is either October or November. These varying patterns are caused by the differing physical origins of the rainfall at different seasons.

The lower east coast receives some of its warm-season rainfall from abnormalities in the easterly flow, i.e., nascent tropical disturbances. The rest of the summer rainfall is attributable to thunderstorms that originate convectively over the Everglades and move toward the coast during the afternoons. The dry-season rainfall here comes mostly from prefrontal squall lines as cold fronts approach from the northwest plus an uncertain amount from occasional low-latitude storms that move eastward from the Gulf of Mexico.

Farther north, cyclonic and frontal rainfall increases while that attributable to tropical influences becomes of lesser importance. The March maximum in the Panhandle is caused by the frequent low-pressure systems that cross the coastline from their birthplace in the northwestern Gulf of Mexico. The late-fall minimum there is due to the large fair-weather-producing high-pressure areas that swing south during that season.
WEATHER CYCLES IN SOUTH FLORIDA

A cyclic variation of some element is its progression from low to high values and back again to low at more or less regular intervals. Considerable attention has been paid to weather cycles by meteorologists and climatologists over the years. Any meaningful grasp of their variability would be of inestimable value to those whose business depends even in part on the weather. For example, the supply of heating equipment sometimes falls short of need when extremely cold weather continues for several weeks. Air-conditioning units and their servicing have been known to fall short of demand in some areas. Fuel, clothing, sports events, etc. are involved. The list could be expanded indefinitely before even touching upon the highly critical essential problems dealt with in agriculture and human water consumption.

Numerous natural and derived cycles have been described. Some of them seem, for a time, to yield usable results; the 23-year sunspot cycle is said to affect the weather, but no one has offered proof enough to make this cycle useful. Another more pertinent example occurs when an apparent decreasing trend in rainfall is interrupted by a wetter period. The question then arises whether this is the beginning of an upturn in the cycle or merely a wrinkle in the rainfall graph. Stock-market trends are noted for just such oscillations, and the first analyst to solve either of these problems, to the point where he or she can make a forecast a season ahead that is 75% reliable, will be performing a valuable service for mankind and at the same time be making a personal fortune.

To establish the reality of a rainfall cycle requires long periods of reliable weather observations. The variation in the average temperature over a long period of time is so slight that very carefully calibrated and sensitive thermometers are necessary, as are observational sites that can be controlled against encroachment by the activities of humans. The same is true of rainfall measurements, which by nature show wide differences from year to year and from place to place.

To implement the requirements for precise observations, the National Weather Service some years ago proposed a plan for *bench
mark' weather stations, each in an environment that could be controlled and standardized—such as the campus of a large university which would not be altered physically in the foreseeable future.

In order to evaluate the performance of the weather over a long period, so-called 'climatological normals' have been developed. A 'normal' is an arithmetic average over a sufficiently long time that the addition of more years of record will make no appreciable numerical difference.

The matter is subject to some interpretation, however, especially for rainfall. There is almost no upper limit to the amount that can fall, but the lower limit, of course, is zero. The result is that the most likely amount of rain for a month is not the long-term average but about 70% of that amount.

To illustrate, suppose that the rainfall normal for Miami in November is 1.20 inches, based upon 30 years of record, 1941-1970. Suppose also that during that last year, the rainfall in November amounted to 15.00 inches—this amount has actually fallen in some earlier year. The November normal would then increase to 1.66 inches. The example illustrates how jumpy the normal rainfall can be when such freaky events are factored into the equation.

Cycles, then, in south Florida as elsewhere, can be very misleading. Long-term fluctuations do seem to take place, but up to now, no one has described a method by which they can be used to forecast for as much as a season ahead. Sorrowfully, we have so far concluded that there are only two reliable cycles in the weather—day and night, summer and winter. It is a truism that all other perceived cycles have a way of disappearing as soon as they are discovered.

Still, we do know pretty well that the rainy season is predictable, as is the dry season of south Florida's winter, and to a lesser extent, that of north Florida. The severe droughts that occasionally are inflicted upon both regions are seldom foreseen. Thus, it is when we try to extend our knowledge of wet weather to predict the start of the rainy season that we often have trouble. In such cases, a few weeks' variation can be important for the preservation of lawns, even shrubbery and the deeper-
rooted orange groves. Power plants have to be shut down periodically for maintenance, and if a large unit is off the line when an unseasonably hot or cold spell occurs, the utilities may have power-out difficulties.

A great deal of attention has been paid to perceived effects of human activities upon long-time fluctuations in the weather. So far, the results have been somewhat imprecise, but there does seem to be a measurable correlation given sufficient data. For example, temperatures at cold locations in the Everglades show noticeable effects of cultivation. In the long-remembered winter of 1940, an authenticated temperature of 14° occurred at Okeelanta, south of Lake Okeechobee. This phenomenally low reading preceded the intensive cultivation in that area. As farming became more general south of the lake, minimum temperatures seemed to rise, as reflected in the records of the now-defunct Federal-State Horticultural Protection Service (the name of which was mercifully shortened to the Frost Warning Service). The service, initiated in 1935 at Lakeland, succumbed a few years ago to budget pressures at the national level; the detailed field temperature survey was curtailed and the forecast activities were transferred to the National Weather Service at Ruskin. In the earlier years of the Frost Warning Service, the records indicated that the mucky soil in undeveloped parts of the Everglades was only loosely packed. The heat radiating away to the sky on calm clear nights was only slowly replenished from the water table lower down. Cultivation over the years tended to compact the soil, making it a better conductor of heat from the depths up to the surface, thus keeping the temperature from falling so low.

As ground cultivation expands, the requirements for water control become more evident. Excessive rainfall periodically damages the spring tomato crop and other crops as well. (The historic heavy rains during the summer and fall of 1947 led to the construction of additional drainage works.) Drier weather during the winter and spring necessitates extensive irrigation both for citrus groves and for truck crops.

Canals dug to drain the Everglades have allowed salt-water intrusion from the ocean to proceed into areas where previously freshwater wells have begun to deliver brackish water. The excessive draw-down
of water for irrigation and industrial purposes has led first to the ex-
haustion of artesian supplies and then to a further systematic lowering
of the water table, causing previously free-flowing springs in central
Florida to go dry.

Temperature effects resulting from human activities are found in
urban areas as well. These effects are characterized by the elevation of
minimum temperatures in the city several degrees higher than formerly
recorded, as compared with readings in unaltered rural areas. Under
natural circumstances in the rural areas, chilly winter mornings in south
Florida are attributable to radiation of heat from the ground to the
atmosphere—the heat radiating more readily outward through dry air.
The air nearest the ground then is cooled by contact with the
chilled surface. The cooled air is denser than the air just above it, so the
denser air drains downhill into any nearby shallow pockets. As these
pockets fill with cold air they gradually merge, like rising water, so that
by sunrise a layer of air of sizable thickness has been cooled.

This process does not occur or is interfered with in urban areas by
feedback into the air of heat stored in concrete streets, asphalt drive-
ways, paved-over parking lots, airport runways, masonry buildings,
and tar-covered roofs. Observers have noted city temperatures on cold
mornings of 4 to 8° C or more above those in nearby rural areas. This
system is known to meteorologists as the “urban heat island”. It should
be pointed out, however, that the differences do not exist on windy
nights or during the daytime since the higher wind speeds equalize the
temperatures by mixing the air.

Another effect of this kind of activity is the subsidence (settling) of
the muck soil of the Everglades. This subsidence is partly the result of
the compacting already mentioned and partly a result of oxidation of
the highly organic soil, brought about by improved drainage and the
exposure of the soil to sun and wind as a result of the removal of the
vegetative ground cover. Photographs taken 40 or 50 years ago dra-
matically illustrate how much soil we have lost, as we see buildings then
resting on the ground but presently resting atop pilings or stilts—the
same ones installed by pounding them into the ground when the build-
ings were constructed.

A concurrent process is the gradual pushing back of housing into the
Everglades. Those of us who occasionally fly into Miami International
Airport can remember when the western outposts of dwellings were
found east of the Palmetto Bypass (SR 826). Now it appears that new
subdivisions spring up almost overnight along the demarcation strip
between city and wilderness. these new developments accelerating the
drainage into the ocean of the urban water supply.

Some observers believe that the Everglades will eventually disapp-
pear, to be succeeded by something resembling a sandy beach or a
moonscape. Long before that process becomes complete, however, we
shall see the disappearance of the lush vegetable crops of earlier years.

Any halt to this inexorable march will require many changes in
human attitudes and activities. Some of these changes may demand a
restudy of land-use programs; some will require a reevaluation of the
cost-benefit ratio of water-control practices. Still others must await a
change in the national economic policy, which today is devoted to
development, urbanization, and feverish construction activity.
SUMMARY

1. Florida lies between north latitudes 24° 33' and 31°, just north of the Tropic of Cancer.

2. Nearness of the Atlantic Ocean and the Gulf of Mexico together with the low latitude result in Florida's subtropical-marine climate. Many tropical plants (e.g. the Coconut Palm) reach the fruiting stage, despite infrequent frosts.

3. The maritime quality of the climate means damp warm summers, infrequent tropical cyclones, and moderate winters — occasionally interrupted by incursions of colder drier air from more northern latitudes.

4. Prevailing winds south of latitude 28° are easterly all summer and half the winter and are from warmer regions. North of 28°, winds are westerly in summer and winter.

5. Florida rainfall pattern:

<table>
<thead>
<tr>
<th>South of 28°</th>
<th>North of 28°</th>
</tr>
</thead>
<tbody>
<tr>
<td>wet summers,</td>
<td>rainfall evenly</td>
</tr>
<tr>
<td>dry winters</td>
<td>distributed</td>
</tr>
<tr>
<td>rainy season</td>
<td></td>
</tr>
<tr>
<td>late May—late October</td>
<td></td>
</tr>
</tbody>
</table>

| wettest month        | September              |
| next wettest         | June                   |
| driest month         | December               |
| wet season rain sources | tropical disturbances, |
|                      | local thunderstorms     |
|                      | over Everglades and     |
|                      | coasts                 |
| dry season rain source | pre-frontal squall     |
|                      | lines                  |
|                      | pre-frontal squalls    |
|                      | followed by fair       |
|                      | weather highs          |

6. Drained Everglades soils absorb and give off more heat; they compact and oxidize resulting in loss (subsidence) of several feet during the past 50 years.

7. Urban heat islands result from heat stored and given off in quantity from paved-over areas.
INTRODUCTION—Part 2

Having reviewed the broad aspects of weather and the more specific views of the climate of south Florida, we have begun to focus more on the cyclical systems—especially those that deal with water in general and rainfall in particular. We have been made aware of the difficulty in predicting cycles and the amount of data required for its execution.

What follows is a closer focus on this problem. There is most evidently a rainfall-water cycle in south Florida that can be seen in the broad view. This is an attempt to explain the ‘symptoms’ of the cycle rather than the ultimate causes, which are beyond our present scope. Yet, the understanding and proper use of the points of change in the multi-year wetter and drier periods may provide us with the insight needed in the investigation of their hidden origins.
RAIN OVER THE KISSEMMEE

Mary Steffee Degtoff

When I was young (I'm seventy-one) big clouds came up here from the South—. We had heavy rains every day in the mornings for a month during the summer, and heavy rains in the afternoons the next month—. The marshes were wet—. During some years the cattle on islands in Lake Kismimmee had to be ferried to higher ground.

Nowadays I understand that sometimes the dry pastures have to be irrigated.

Everyone knows that our flowing wells have quit flowing—.

Mary Steffee Degtoff is chairman of Friends of the Everglades for Osceola County where she was born and has lived all her life. Her grandfather was captain of a steamboat which ran down the Kissimmee River to Okeechobee and the Caloosahatchee. She remembers the occasional flooding of the river, up to the house where she lived. This flood brought nourishment to the marshlands. Her testimony as to the constant rains of summer is eloquent proof of the changes that have occurred in the Kissimmee Valley since the canalization of 1969. The slow drying up of Everglades ground water has had a disastrous effect on Everglades rainfall by which, in turn, the supply of fresh water to the area of south Florida has diminished.

—Ed. note.
MULTI-YEAR RAINFALL CYCLES
IN SOUTH FLORIDA

Jessie Freeling

One can wonder at the reluctance of the authorities who manage our water resources to predict the multi-year cycles of wet and dry years. Their observable indications are plain in continuous water level measurements, and signs of them are quite visible in changes occurring in plant and animal behavior. This is the case to such an extent that those who are familiar with the wetlands may often take these changes for granted. The admitted confusion on the part of the agencies with regard to predictability has prompted this discussion of certain observations made for many years in south Florida.

Some of the predictive problems are based on the inability to pinpoint the *onset* or *termination* of rains on a per-year or per-cycle basis. The use of the term ‘cycle’ is done advisedly since we will see that *in lieu* of onset times, etc., the cyclical effects of rainfall occurrence would be more apparent if a comparison of groupings of wet years (or dry years) were made.

A major point is that in nature there are cycles within cycles, and an emerging picture or pattern may be more discernable by determining whether there is a large cycle that contains within it other cycles. In order to show this, it is usually necessary to make observations over a long period of time. As an example we can select tidal cycles. In any given area, there may be one or two tides per day (highs and lows). Per month, the amplitude of the highs and lows change, and the amplitude of these over several months also approaches maxima and minima on a *per-year* basis. Seemingly, the forces governing tides are more predict-
Figure 2 — Tub experiment (see text). Partly filled tub with floating rings fixed in position. Tub water represents ground water. Rings represent rain gauges. Hose spray represents rain.

A. Most of the rain falls through the rings.
B. Though it has not rained enough to fill the tub, the gauges register a large volume.
C. Most of the rain misses the rings, but...
D. The tub overflows.
able than those controlling the weather. Yet, there are local and regional factors that complicate the process, e.g., winds, the shape of the bottom, latitude, etc. But, by plotting averages over several years, a predictable pattern emerges.

Our rainfall cycles are likewise comparable, i.e., each year there is a wet and a dry season. But, there is also a larger cycle lasting several years when the wet seasons are wetter each succeeding year, approaching a peak level, after which they become less wet each year, leading finally to a series of dry years. One of the problems in using these data is that the study of rainfall records alone do not produce the key to understanding the cycles. This is because there are not enough rainfall-detecting stations to get a satisfactory average of the rain distribution.

Consider the following simple experiment. Take a tub containing some water. This will represent the ground water. (Note: For our purposes, 'ground water' is that water usually under the ground surface but visible in lakes or ponds. In south Florida wetlands, however, during part of the year in some areas, or in other areas during intermittent years, the water level may be high enough to be above the ground surface. In these cases, surface water and ground water are continuous.) Float a few small plastic rings on the surface of the tub, and anchor them in place to keep them from moving about. These rings will represent rain gauges at scattered weather stations. Then turn on a hose at various intervals directed at random points over the water surface; this will represent the rain.

It can be seen that only the rain falling through the rings gets measured. It is then possible that all the rain will fall through the rings but only half-fill the tub. On the other hand, the rings could be avoided entirely and the tub filled to over-flowing. In the latter case, there would be a flood, without recording any rainfall; while in the former case, many data would be recorded but with only a half-filled tub. These particular examples may seem to be extreme, but they make a point of the impracticality of the exclusive use of rainfall records for this type of study.
Figure 3 — The wet—dry cycle (see text). Shown are a pond; three rocks in the ground enclosing a fillable space; the water line going from the ground below the pond, during the very dry year, to cover the land adjoining the pond during the very wet year; vegetation appearing in wet years only; and a difference in rain quantity from year to year (sparse to fluffy to dark clouds). One full cycle from a driest year through wetter years and back to the driest year is shown. Note also the change in water level in the ground each succeeding year. This is a graphic example, and although 5 years are shown for this cycle, in reality it may be longer (see graph of rainfall data).
Personal observations have been based on something much closer to reality, viz., the ground water as seen in a swamp, a pond, or a series of ponds of different depths. Here, high or low water levels do not depend so much on how much rain falls at a given time, but rather on how much water has accumulated in the ground.

Let us observe one natural pond which must be free from drainage or other external manipulation for several years. At the beginning of our observation period, the pond is dry for 6 months; then during the rainy season, the water level rises and expands. When the rains are over, the water gradually recedes until the pond appears to be dry again, however, there is ground water present just below the dry bottom. In 4 months when the rains recommence water appears in the pond itself. Because the pond water appears sooner than during the first go-around, you become aware that the cycle is getting wetter. Although you do not yet know how much more rain will fall, the ground water level has reached the previous year’s level sooner. More rain will make the current year wetter, and the wet cycle is on.

Now, when the rains stop, it takes the water longer to recede because there is more of it below pond level, and the pond itself only gets dry just about a month before the water begins to reappear in the next wet season. Water levels will be much higher, and there will be more rain than during the previous year. During the following year, the pond may not even go dry.

Thus at this point, if you have been comparing this cycle with the general rainfall trend: 1) there has been more rain each year; 2) the pond is at its highest multi-annual state; 3) observation of this is further confirmed by the type and amount of growth of surrounding vegetation; and 4) the cycle is due to change this current year or the next.

Suppose the following year produces less rain. It will nevertheless be a wet year since the ground water level is high—even at its lowest level for the year, and all forthcoming rain is added to that level. But the fact that there is less rain and a not-quite-so-full pond is a signal that the cycle is starting to change. Even with still less rain the following year, it will be a fairly wet one, however, the pond may dry up for a short time.
TABLE 1 — SOUTH FLORIDA RAINFALL CYCLES

The following chart and graph are based on NOAA figures supplied by the National Climatic Center, Asheville, N.C.

The south Florida area considered includes the EVERGLADES AND SW COAST and LOWER EAST COAST divisions. The annual rainfall from the two divisions was averaged. Each of them obtain data from several locations. As an example of the variation within each station group, in the year 1978, the Everglades...
division with 14 locations showed a total rainfall range from 45.69 to 66.22 inches. In the lower east coast division, with 12 locations, the variation was 45.83 to 74.35 inches.

The table shows the annual rainfall in inches obtained by averaging the annual figure of the two divisions. Next to the annual figure, the difference (positive or negative) between it and the accepted average annual rainfall figure is listed. The accumulated loss or gain is the difference between the figure in the second column and that of the third column of the previous year. Thus the accumulated figure tells you what you
are gaining or losing through a period, or what your surplus or deficit is in the long
term.

In the figure, the light line shows inches of rainfall each year. The heavier line
shows the accumulated amount above or below average. It should probably be higher
in relation to the average (normal) line because there would have been some accumu-
lation before 1941, but it was necessary to start somewhere. The purpose of the com-
parison is to show the long term direction changes.

The curves certainly indicate a cyclical occurrence of rainfall, especially the
accumulated values. Perhaps if there were more rainfall recording stations or if the
ground water levels had been monitored, the cycles would be clearer. Noteworthy is
the accumulated deficit in rainfall since 1969.

**SOUTH FLORIDA RAINFALL CYCLES**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ANNUAL RAINFALL (inches)</th>
<th>+ or - average</th>
<th>ACCUMULATED</th>
<th>+ or - average</th>
<th>ACCUMULATED</th>
</tr>
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<tr>
<td>1941</td>
<td>59.28</td>
<td>+ 2.85</td>
<td>2.85</td>
<td>1961</td>
<td>40.33</td>
</tr>
<tr>
<td>1942</td>
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<td>- 0.57</td>
<td>2.28</td>
<td>1962</td>
<td>51.03</td>
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<tr>
<td>1943</td>
<td>49.47</td>
<td>- 6.96</td>
<td>4.68</td>
<td>1963</td>
<td>50.25</td>
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<tr>
<td>1944</td>
<td>41.12</td>
<td>- 15.31</td>
<td>19.99</td>
<td>1964</td>
<td>54.03</td>
</tr>
<tr>
<td>1945</td>
<td>51.65</td>
<td>- 4.77</td>
<td>24.76</td>
<td>1965</td>
<td>54.06</td>
</tr>
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<td>52.89</td>
<td>- 5.54</td>
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<td>1966</td>
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<tr>
<td>1947</td>
<td>83.85</td>
<td>+ 27.42</td>
<td>0.88</td>
<td>1967</td>
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</tr>
<tr>
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<td>1968</td>
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</tr>
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<td>+ 0.59</td>
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<td>1969</td>
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<td>45.99</td>
<td>- 10.44</td>
<td>5.69</td>
<td>1970</td>
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<tr>
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<td>1971</td>
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<tr>
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<td>- 5.89</td>
<td>22.12</td>
<td>1972</td>
<td>56.36</td>
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<tr>
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<td>12.65</td>
<td>1973</td>
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<tr>
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<td>44.82</td>
<td>- 11.61</td>
<td>17.83</td>
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<tr>
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<tr>
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<td>19.62</td>
<td>1978</td>
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<tr>
<td>1959</td>
<td>69.56</td>
<td>+ 13.13</td>
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<td>1979</td>
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</tr>
<tr>
<td>1960</td>
<td>65.33</td>
<td>+ 8.90</td>
<td>2.41</td>
<td>1980</td>
<td>47.91</td>
</tr>
</tbody>
</table>

The subsequent year or two will produce less rain, and the pond will
dry up for up to 6 months. This is the driest stage at which we originally
began observations. In following the rainfall trend, we observe at this
point that: 1) there has been less rain each year; 2) the pond is at its
driest stage; 3) ground water below the pond is at its lowest level;
4) vegetation of the surrounding area has returned to the way it was during the previous cycle’s driest years; and 5) the cycle is due to change in the current or following year. Suppose that the rainfall increases the next year. Even if it does so a great deal, it will still be a dry year since most of the rain will be adding to the ground water below the level of the floor of the pond. Nevertheless, the cycle has turned to the wet period.

Using rainfall records alone, one can use a simple calculation to obtain figures which when graphed, will conform more or less to the pond observations. By taking the average rainfall figure for an area (derived by authorities after several years of observation) and the annual recorded rainfall figures for a series of years (as many as possible), one can calculate the accumulated loss or gain (with respect to the average rainfall figure) on a continuing, year-after-year basis.

While the calculated rainfall results conform to the ground water observations, they tend to reflect more the local variations and add to camouflage the overall areal effects of rainfall accumulation. In addition, they do not show the ‘inertial’ aspect of water accumulation or loss during the early part of the cycle.

The apparent lack of change during the first year in a cycle change is explained by the fact that there is the accumulated space in the ground yet to be filled up. Large increases occur as wet years succeed each other and the sub-surface levels fill. There also seems to be a greater increase in the rain at such times. Likewise, when the rains begin decreasing annually, there is not as great a change during that first ‘decrease’ year since the sub-surface levels are still relatively full of water. Serious drought comes when drier years follow each other, and the sub-surface spaces begin to dry out. There also seems to be concurrent decreasing rainfall. The year in which the rainfall amounts change direction from wetter to drier, or vice versa, thus cannot produce a significant water level change in either direction, but the change in rainfall amount should be interpreted rather as a ‘signal’ that the ground water level change is coming in the next year or two. The number of years required for the complete cycle is variable, but the signs of change occur in advance of marked effects, making anticipation possible.
This is, of course, a natural system and predictable. It is necessary, however, to make observations in a location where the natural system can be observed—one not subjected to the human manipulations of draining and pumping. Being natural cycles, there is a definite correlation with the life cycles of native animals and plants—their population size, blooming, fruiting, etc. For example: referring to Sandhill Cranes,—“There seems to be a correlation between the percentage of adults with young and the number of broods-of-two with rainfall”—James M. Lane, Archbold Biological Station, 1979; and—“Alligators appear to lay their eggs higher above the ground in wet years than in dry years”—James Kushlan, Everglades National Park, November 1980. Those who are in wildlife management should be cognizant of this cycle system rather than to put all yearly cycles on an equal footing. The latter will tend to confuse the observation of both plant and animal cycles which are already adapted to the natural multi-year cycle.

Thus some species may be favored one year and others the next; i.e., some plants appear only in wet years, others in dry years—a natural version of crop rotation. Man’s selecting one way to manage water levels every year favors certain species all the time and selects against others all the time. Water management authorities should not only anticipate these water cycles, but should allow them to prevail in managed areas.

With proper anticipation, water could be gradually released before dangerously high levels occurred or retained with no fear of flooding when shortages occur—keeping the cycles intact but tempering the extremes. Land-use development could be planned economically to allow for these expected variations. The long-range point of view is the most economical way as well as the least destructive.
SUMMARY

1. Rainfall cycles are multiannual with successive years becoming drier and then wetter. Measurements should be made continuously to understand them rather than to consider each year as a separate entity.

2. Insufficiency in number and placement of rain gauges do not allow for a realistic assay of quantity or frequency of rains over the south Florida area.

3. Observation of ground water level together with available rainfall data show the progress of the wet or dry season and whether or not the year will be wetter or drier than the previous one.

4. When wet year cycles change to dry year cycles, using this system, one may be able to tell when the cycle is about to change.

5. Using the average rainfall figure for an area and the annual recorded rainfall for as many a series of years as possible, one can calculate the accumulated loss or gain in rainfall with respect to the average figure. The curve of these data versus the calendar year generally follows the ground water data. Thus one can construct a graph that generally shows wet and dry cycles.

6. These are natural cycles to which plants and animals respond in their roosting, growth, and reproductive behavior.

7. Land-use can be planned more economically when one is aware of the ground water aspect of the cycles by keeping them intact but controlling their extremes.

INTRODUCTION—Part 3

Thus far, we have dealt with general aspects of weather and climate and some aspects specific to south Florida. In particular, the water environment of the region has considerable personal importance to us. We are surrounded on all sides by water—both fresh and salt, but in addition, each of us requires consumption of about a gallon per day. If to this we add the amounts used for the personal needs of bathing, cleaning of utensils and clothes, and sanitary uses, the
average daily consumption comes to about 200 gallons per person. Bear in mind that we are referring to this amount every day for every person in the community. We therefore need to be assured about the quantity of the water available as well as the quality of the water that comes in contact with our bodies.

In addition to the direct consumption of water, we need to consider the fact that it affects the very environment in which we live. Our subtropical climate, which is characterized by a hot, humid rainy season and a cooler dry season, involves a great deal of water that is demanded for cooling and sanitation during the former period and for lawn and crop irrigation during the latter. We are a growing population, and in order to live here, we have drained much of our lowlands so that the construction of homes and businesses could proceed. A major factor in these businesses are the many visitors who arrive from the north during the dry season and whose presence makes even more demands—both direct and indirect—upon the water services.

Is there a limitless supply of water that we can tap as needed? In a sense, there is. After all, most of the earth is covered with water, and as any satellite picture of the earth planet will show, there is a thick cover of water clouds. But we have neither the technology nor the understanding to take complete advantage of these factors. In fact, the available water supplies are somewhat limited, and before we consider taking advantage of all of these, we ought to be familiar with what the existing and natural supply there is on this resource.

Much has been written recently about the water cycles in this area, and a good and reliable technical base of references that provide readable information are recommended to you (see REFERENCES). Our purpose here is to make the necessary and available information understandable.
THE WATER CYCLE IN SOUTH FLORIDA

Leonard J. Greenfield and
Patrick T. Gannon, Sr.

As our discussion has already implied, the forces that control the weather—in fact all the processes of weather—act as movers and carriers of water in the recycling sequences. Also, we are very much aware of the fact that the solid components that form the soil are both the physical and chemical parts of the mechanism of sub-surface uptake and storage of water. The natural levels of soil and rock and the recently constructed levees and canals also influence the flow of water and the amount of water available to the atmosphere. Historically, these flows from the north were once much greater and more influential, but now are of a lesser nature because of drainage practices and because of their interruption and accumulation by the Conservation Areas. The flows are still very important to the southern tip of Florida and to Everglades National Park.

So we now have three physical situations that serve as direct water sources to you and your immediate environment and are linked to each other in a cycle. As it happens, at any given location, any one or more of these situations may be most important as a water source to you personally. But because of their linkage to each other, just how you handle your water source is critical, and, as you will learn, other parts of the cycle not only interlink, but have additional specific effects on you. Now let us examine these links—and bear in mind that we, singly, and in a group, as users of water, are also one of the links.
WATER FLOW—SITUATION 1

We can dispose rapidly with the subject of water flow in south Florida since this is most affected by drainage canals and levees constructed since 1945. This is also dealt with extensively in the references we have given. Essentially, Lake Okeechobee drains 4700 square miles of the Kissimmee Basin. Divides are not well defined so that the direction of surface drainage may be determined by the distribution of recent rains. As we have said, significant flow to the tide waters is only in the southern tip of Florida—now within the Everglades National Park. Collier County gets no water from the Lake, and the rain that falls in the northeast part of Collier County goes into Conservation Area 3.

In western south Florida, the original Big Cypress Swamp watershed has been severely altered by the construction of the Golden Gate Canal and Faka Union Canal Systems. As a result, the pattern of sheet flow through the western part of the Big Cypress to the Gulf is changed to one of irregular flow through the canal system. The eastern half of Big Cypress is unchanged with regard to drainage construction, and natural surface flows continue to the northwest portions of Everglades National Park.

In Monroe County, the Keys depend entirely on rainfall (we are speaking of natural water flow mechanisms and not the pipeline or desalination plants).

The coastal ridge from Palm Beach through Dade County is the eastern boundary of the Everglades waterway. The waterflow curves to the southwest—away from the ridge—and characterizes the Shark River Slough in west Dade County.

The drainage and flood control systems have produced drastic effects whose results merit close scrutiny in our discussion to follow—and for the future of the area.

GROUND WATER AND WETLANDS—SITUATION 2

Once it has fallen, the rainwater becomes involved in several processes. Part of it evaporates; part is taken up by plants; part of it is ab-
sorbed by the soil itself; and part recharges the water underground in
the deeper soil and in the aquifers. The fact that so much water is under-
ground was already discussed. Also, one can observe that excavations
into the ground are quickly filled so that we know that water tables are
at or near to the surface in south Florida.

The aquifers are of great interest to us because therein lie the daily-
use waters so important to the growing populations we have referred to.
The Biscayne Aquifer, which is under southern Palm Beach, Broward,
and Dade Counties provides water for the population centers located
there along the east coast. Southwest Florida has a shallow aquifer
along the west coast that thins out in central Collier County and wedges
out near the east edge. Lee, Hendry, and most of Palm Beach counties
have local discontinuous aquifers of low yield, and in addition, in Palm
Beach and Martin Counties there is a coastal aquifer of moderate yield.

Aquifer recharge used to be (i.e. before the 1930's) primarily from
rainfall. Now, however, they may be mostly from canals. Although the
volume of recharge may be the same, it may be of entirely different
quality than before.

Historically, south Florida was a region covered with water at least
part of the year, in areas of low relief. Now, because of drainages and
the diverting of water flow, some areas are never covered with water,
and in other areas, such as those with many canals, ground water is
always exposed. It is important to mention this aspect because of what
once existed (and still does in certain areas) in many parts of south
Florida.

In the past, much of the area west of the Atlantic Coastal Ridge and
up to the western Flatlands was wetland. That is to say it was flooded or
wet at least part of the year. Moreover, it was covered with vegetation
and various types and thicknesses of soil. In many of the areas, there
was a high content of organic material in the soil which originated from
decay of leaves, water plants, Sawgrass, etc. The porous rock aquifers,
the soil above it, and the plants in the soil formed a very active system.
The activity was such that water was filtered before charging the
aquifer, and also by means of chemical and biological activity, soluble
substances such as iron, nitrates, phosphates, etc., were removed and stored. Also the soils and plants exercised a very important control on: the evaporation of water to the atmosphere; the temperature of the ground; and the temperature of the air layers near to the ground. It is these latter three areas that involve us so importantly in the water cycle.

If we consider the area of south Florida before 1900, 75% of it was wetland. Remember again at this point not to think of wetland as continuously flooded, but rather as flooded or wet or with the water level so close to the soil surface as to support the so-called wetland vegetation. Many areas of course were continuously covered with water or covered for at least part of the year. Drainage practices have lowered the water level in southeast Florida 5 to 6 feet below the 1900 level. 2 to 4 feet in the 75 square mile area around Naples, and an undetermined amount over the Big Cypress Watershed. Thus about 35% of the south Florida wetland no longer exists. The land thus exposed has been converted to agronomic or urban development use. This trade-off has produced many drastic effects such as: loss of soil due to oxidation, increased frequency of fires, and some sea water intrusion into ground waters. The land development and its effects are discussed elsewhere rather extensively. Here, we are going to consider only the climatic consequences of this type of activity and how we are linked with it to the water cycle.

WETLANDS, WATER CYCLES, AND WEATHER IN SOUTH FLORIDA—SITUATION 3

The climate in south Florida has already been referred to as subtropical marine with long, warm, rainy summers and mild, dry winters. The extremes in temperature are modified by the ocean to the east and the Gulf of Mexico to the west which warm the air in winter and cool it in summer. The absolute humidity is high in summer and can increase during the day; however, as the temperature rises during the day, the relative humidity usually decreases.

There is a nearly constant southeast breeze across the warm Gulf Stream which tends to prevent northern cold fronts from reaching
south Florida—although an occasional cold front invades the area and frosts occur.

The average annual rainfall is about 60 inches, two thirds of which falls during the June to October period. These summer rains are sudden, localized, brief, and intense. Winter rains, however, are associated with cold fronts. Occasionally also, tropical hurricanes hit south Florida in the summer and fall.

You may recall that reference was made to those aspects of weather dealing with large powerful systems that dominate situations on large parts of the earth (global), systems that moved into and dominated sections spanning countries, states, ocean, etc. (synoptic), and to regional or areal situations down to county, lake, or smaller size (mesoscale).

The hurricanes that occur occasionally and the cold fronts of the winter are synoptic features whose energy and geographic extension overpower whatever local conditions are generated. Thus, one would think that because of the forces driving these features, local or mesoscale conditions can generally be overlooked as inconsequential. Most often, weather predictions appearing in the communication media do precisely that—even though mesoscale systems are the prevalent ones during quiescent intervals between frontal movements. In fact, in south Florida, the weather during the rainy summer period (June—September) is strongly influenced by mesoscale conditions. Furthermore, up to \( \frac{2}{3} \) of the summer rainy days are influenced by mesoscale rather than synoptic scale disturbances (Personal communication 1981: Dr. Larry Lahiff, National Hurricane Research Laboratory). Thus a significant (but variable) percentage of south Florida rainfall is caused by mesoscale systems.

Since these types of occurrences are so very important in our area, we need to elaborate on some of their technical aspects. Your understanding is important because not only is your local weather and water supply effective on you personally, but as you will see, the activities of our local population can have a profound effect on the present and future weather conditions.
The important technical aspects are issues—in the same sense as those issues with which we deal politically. They have the same or greater level of importance, but differ in that they all present a measurable aspect of reality. They are devoid of creed or emotion—they just are.

BASIC TECHNOLOGY OF WATER CYCLE ISSUES

1. HEATING OF WETLANDS.

Returning once again to the concept of wetlands, we are dealing with a vast area whose attributes range from actual water bodies to soil with a high moisture content and with a vegetation cover of 0 to 100%. Picture a water surface in the wetlands which is subjected to solar radiation. Water has many unique properties, and one of them is that the surface of a water body is slower to heat or cool than most other solid or liquid surfaces. The solar radiation that is taken up at the water surface moves downward; i.e., it begins to heat the water surface, and the heat moves downward. It continues downward because the molecules of water, which were moving generally in that direction, move faster when they are heated. In this manner, maximum heating occurs at the surface, and the water is mixed by movement of the warm water molecules in a process called 'convection.' Now you can see readily that a thin layer of water will heat up faster in the sun than a thicker layer because there is less vertical distance for the warmed water molecules to move. By the same token, in the darkness, the heat stored in the water can be lost to cool air faster from a thin water layer than a thicker one.

One must also remember that warm water is more buoyant than cooler water (just as with warm and cool air). Thus when a warm water surface is cooled it sinks (or rather, the water system overturns) and there is convection and mixing of the water layers. This may occur by contact of the water surface with cool air or, most dramatically, when a cool rain falls.
We have only mentioned the rate of water heating and cooling. In addition, the water can store or hold considerable heat, compared to other substances, and we say that it has a high 'heat capacity'. Because of this capacity and slowness to heat, or conversely, to lose heat, we may find that water in the wetlands under the spring or summer sun all day may be warm to the touch, even at night. To be sure it will be cooler than it was during the day, but still it will be warm to the touch. This difference in temperature between night and day that does occur is called the 'daily temperature range'. It should be clear, because of what we said about thin and thicker water layers, that with the increase in thickness or depth of water, the daily temperature range will decrease. Thus a pond in the Everglades that is 5 inches deep and subject to all-day sun in spring or summer will have a daily temperature range of 14° C (28° F), whereas such a pond 12 inches deep will have a range of 9.5° C (18° F). (Remember that we are speaking of the range in temperature—and not what the actual temperatures were.) If we are more aware of the fact that there are a great number of ponds in the wetlands or many areas in which the land is submerged to the depths used in the above examples, we should also be aware that there is a great deal of heat energy being transferred and stored in the course of each day. The energy absorbed by the water surface, which itself is warmed, as well as that absorbed by the lower atmosphere, which is also warmed, is called 'sensible heat'.

But only part of the energy absorbed by the water is used in the heating process. Some of the solar energy is used to evaporate water from the wetlands to the atmosphere—as water vapor. That portion of absorbed solar energy used for evaporation is known as 'latent heat'. What happens is a consequence of the fact that the water molecules require energy to escape the water status and to remain in the highly excited vapor stage. As the vapor is formed, it removes heat from the water surface and keeps it as energy in the vapor particles. When the vapor condenses and re-forms water in the upper atmosphere, that energy is released again as heat which now becomes sensible heat.

The water vapor, produced by the process of 'evaporation', not only comes as a result of absorption of energy by water surfaces, but also by
TABLE 2 — SENSIBLE HEAT AND LATENT HEAT FACTORS

Heat capacity = the quantity of heat in calories required to raise the temperature of a system or substance 1° C. The term 'specific heat' is often used and implies that the foregoing applies to 1 gram of substance = calories/gram °C

Heat Capacity (approximate)
over the range of 'normal'
conditions in cal./gram °C

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<tbody>
<tr>
<td>1.0</td>
<td>Water</td>
<td>.2</td>
</tr>
<tr>
<td>.5</td>
<td>'Average' soil</td>
<td>.2</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td></td>
</tr>
</tbody>
</table>

or, 5 × more heat is absorbed by water than soil to raise its temperature 1° C.

2 × more heat is absorbed by water than wood to raise its temperature 1° C.

between 2 & 5 × more heat is absorbed by water than peat or muck to raise its temperature 1° C.

or, soil, wood, peat and muck heat up more readily than water when under solar radiation.

Thermal conductivity = the speed of transfer of heat by conduction through a unit area to produce 1° C difference in temperature = calories/second/square centimeter/°C

Thermal conductivity (approximate)
over the range of 'normal' conditions
cal./sec./sq. cm./°C

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<tbody>
<tr>
<td>.001</td>
<td>Water</td>
<td>.1</td>
</tr>
<tr>
<td>.008 — .112</td>
<td>'Average' soil</td>
<td>.2</td>
</tr>
<tr>
<td>.1 — .2</td>
<td>'Average' woods</td>
<td></td>
</tr>
</tbody>
</table>

or, soil heats up 1° C 10 to 100 × faster than water
wood heats up 1° C 100 to 200 × faster than water
peat & muck heat up 1° C 50 to 150 × faster than water

or, soil, wood, peat & muck heat up faster than water.

Thus with regard to 'sensible heat', water absorbs a larger quantity of heat with a smaller change in its own temperature. It distributes that heat more slowly — by convection (see Figure 5). Solids use more conduction (heated molecules 'vibrate' faster and 'pass' the vibrations to adjacent molecules — a faster process).
In reverse, under cooling conditions, water releases heat more slowly but in larger quantities while changing its own temperature slightly. Hence, water has temperature 'control' over the environment.

**Vaporization of water.** The *heat of vaporization* of a substance is the amount of heat required to convert a liquid to vapor in calories per gram. Other factors are involved such as the temperature and the vapor pressure. For the sake of simplicity we will set these factors aside and deal with approximate figures. For water, the heat of vaporization is approximately 400 calories/gram. For some other known liquids:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Heat of Vaporization (cal./gram)</th>
</tr>
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<tbody>
<tr>
<td>Chloroform</td>
<td>45</td>
</tr>
<tr>
<td>Benzene</td>
<td>90</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>95</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>200</td>
</tr>
</tbody>
</table>

Thus, at ambient temperatures, it takes about 400 x more heat to vaporize water than to raise its temperature 1° C.

In our latitude during sunny spring or summer days during peak hours, approximately 0.012 calories, square centimeter, second reach the ground through the atmosphere.

1 gram of water = 1 cubic centimeter. If a cubic centimeter of water were to be spread out to a single flat layer 102 centimeters square, i.e., with an area of 100 sq. cm. (16 sq. inches) — this is of course not strictly true; it would spread to a much greater area —, that 100 sq. cm. would be hit with 1.2 calories per second.

This means that it would take about a second to heat that layer of water 1° C or 5 minutes to *completely* evaporate it. But one must remember that when only a tenth of this energy per sq. cm. hits the surface, the water molecules may move away from the surface because of the thermal conductivity so that it will require more than 10 trips back to the surface (some energy is lost in travel). If this period would be about 10 minutes, then it would take about 10 minutes to raise the water 1° C or about an hour to evaporate it.

In reality, not all the surface molecules move up and down at the same time or rate, the humidity of the air may be high, the beginning temperature may be high or low, etc., so that the *exact* time required to heat or evaporate must be measured in the field. The above example is given as a point of reference. See Figures 5 and 6 on sensible and latent heat.

Thus, the water mass can become sufficiently heated over a short period of a few hours, and a considerable amount of water can be evaporated. The problem is that at warm temperatures in bright sunlight it is not possible to tell easily just how much of sun's heating goes into sensible heating and how much goes into evaporation without knowing the individual situation.
Figure 5 — Sensible heating of water. A shallow pond under solar radiation; graphic
depiction of a small volume of water at and below the surface. Three layers of water molecules are shown from the surface down.

The extent of heating is indicated by dark or shading and the area of the molecule covered.

A. Surface molecules (1) joined to form a surface with measurable ‘surface tension’. A second (2) and third (3) layer; all layers with the same temperature, and presumably with the same temperature as the air above. Molecules in each layer may move in various directions and exchange position with other molecules. Not many molecules break the surface chain to release water molecules as vapor.

B. Surface molecules are heated by solar radiation. They move faster, and those with a downward component (1) move to the second layer position and force an exchange of place with the molecules there (2).

C. Molecules of former layer (2) are now at the surface. Molecules (1) have lost some heat by moving to the second layer but still have enough speed and heat so that those with a downward component can force an exchange of position with (3). Molecules (2) haven’t yet heated because water surfaces heat more slowly than other surfaces. The reason for this and for the position exchange of (1) (3) is because water is slow to heat and slow to cool (has a high heat capacity).

D. Molecules (1) in moving to the lower position have lost more energy (heat) but are still warmer than during period A. Molecules (2) are heated by solar radiation and will force an exchange of position with (3).

E. Molecules (3) are at the surface not yet heated. Molecules (2) and (1) exchange position and either exchange or lose heat, but they are still warm.

F. Surface heated molecules (3) now force an exchange with (1) (still warm). Layer (2) has lost some heat during movement but is still warm.

G. The exchange between (3) and (2) is like that of (2) and (1) in E. Molecules (1) now at the surface are still warmer than they were in A.

H. Molecule layers are in the position they occupied at A but are warmer. Now solar radiation warms (1) to warmer temperature than it did in B. The exchange among molecules occurs again and deeper as molecules get even warmer at the surface and move to exchange with lower and lower layers.

X. Eventually, the surface and several layers are warmed, and if solar radiation becomes more intense or operates over a long period, the water body may become uniformly heated. At night, surface layers will lose heat and exchange position with upward moving warmer molecules from lower layers which displace them. Thus heat is lost from the water and gained by the air in contact with it.
Figure 6 — Latent heat of water. The same shallow pond undergoing sensible heating has received enough radiation to allow for vaporization of water.
A. The pond continues to receive radiation. It warms further.

B. In addition, the surface molecules ‘break’ bonds with each other, and...

C. Change their state from water molecules to water vapor (a gas), a state which is highly active and agitated. The warm active gas particles disperse upward and away from each other (expansion) thus removing heat from the water surface. The new surface is cooler.

D. As the vapor rises, it cools and loses some of its heat energy to its environment. The gas particles slow their movements, begin to accumulate (stay closer together) since their movement is less vigorous.

E. They come together, losing all remaining heat to the atmosphere finally...

F. Coalescing to form droplets (condensation) which eventually fall back down to earth.

evaporation from wet soil.

There is also another extremely important evaporative process called ‘transpiration’. Transpiration is a biologically active procedure by which plants evaporate water to the atmosphere. Mostly, this takes place as a regulatory or physiological process in the living plant leaf at fairly specific locations on its surface. The reason for emphasizing the importance of transpiration is that plant leaves have the capability of evaporating up to 3 times the amount of water vapor from an equivalent surface of water. Thus the quantity of water transpired by plants is such that the term ‘evapotranspiration’ is used routinely to include evaporation from the water and soil surfaces and transpiration from plants.

Summarizing the technical aspect of this issue; some of the sun’s radiation heats the water surface and air levels adjacent to the surface are most strongly heated by being in contact with it. This is termed ‘sensible heating’. Some of the radiation is used for ‘evapotranspiration’. This absorbed radiation is termed ‘latent heating’.

Let us consider how these different types of heating affect us, and how it is that we can in turn influence the local condition. First, it must be understood that we are only now arriving at a point where we can predict the type and order of magnitude of the ultimate effects on the
mesoscale. This is because we are only beginning to collect and put together enough data to simulate all of the mesoscale processes involved. Thus we do not know just how much of the absorbed radiation is involved in sensible heating or in latent heating in every case, however, we have enough surface information to make generalized predic-

Figure 7 — Sea/Lake breeze — Land breeze (see text). Sea/Lake breeze. Warmer air from land rises and is replaced by cooler air over water. This is a strong breeze. Land and air over land warmed by the sun.

Land breeze. Warmer air over water rises and generates weaker breeze of cooler air from land. Occurs at night when land has lost heat absorbed during the day.
tions on at least a climatological basis. Observational and numerical progress has recently been made in several areas. For instance, the process of transpiration increases with downward directed radiation from both the sun and from radiation emitted by the atmosphere. It also increases with the speed of the wind, but the latter itself varies with the shape of and roughness of the terrain over which it blows. Also, transpiration can be countered by the local humidity. Thus, information concerning the process in wetlands vegetation is incomplete and often contradictory.

On the other hand, examples can be given of specific cases, some of which are about or pertinent to our own situation. Let us consider some of these examples, with some degree of conservatism, to see if we can clarify our own involvement. Essentially, we will refer to the factors of heat, evapotranspiration, and wind all on a local or mesoscale.

Consider an arid area where there is located a swamp, all under sunlight and little or no breeze. So much water can be lost by evapotranspiration in the shallows to the atmosphere up and away from the area as to be considered a ‘wasteful’ function. If instead this were to be a humid area, the available water would be conserved. Evaporation might be countered by condensation of rising vapor by taller vegetation. Transpiration might be retarded by the humidity to such an extent that the plants would ‘hold’ the water they take up in their roots, and water conservation could even be increased by putting more plants in a lake. This suggests strongly, that before draining or clearing a swamp, the effects on the overall water budget should be determined.

2. LAKE AND SEA BREEZES.

We need now to bring in the issue of sea breeze and lake breeze in a very general sense. Recalling the fact that water surfaces heat and cool very slowly also indicates that drier land surfaces do so more rapidly. During daytime under sunlight, the land surface near a body of water or wetland will become warmer than the adjacent water. The air over the land also becomes warm and expands; it becomes less dense and therefore its downward pressure is less than that over the nearby water. A
breeze (sea breeze or lake breeze) then occurs as the cooler and denser air from over the water surface flows in and under the warm air over the land. This warmer air rises, cools, and flows over the water to replace that air which moved inland, and a 'circulation cell' is formed. At night the reverse occurs. The land surface cools faster than the water; the air in contact with the land becomes cooler than that over the adjacent water; and it then flows in and under the less dense layer lying on the water. This 'land breeze' is a much weaker system than that which occurred during the day, and the return flow aloft is likewise weak and diffuse. The sea/lake breeze vs. the land breeze system can be altered by general winds coming into the area (e.g., trades, cold fronts, etc.), irregular coastlines, and rough or forested terrain. Consequently, we cannot generalize too much without considering all the factors that may alter the situation, and only expensive complex 3-dimensional numerical models can process all the surface and atmospheric data to determine the influence of important factors (see Figure 7).

Nevertheless, sea/lake breezes are a very important issue in the mesoscale weather of south Florida, and again we can use actual occurrences to depict this. The following example is one of characteristic land breeze with movement first dominated by the strong wind and then with weak and diffused return flow. When a cold front moved into the Lake Apopka area in January, 1977, temperatures dropped severely on the land on the night of the 19th. The lake was still warm, however, and its dimensions (13 km (7.8 mi.) across and a mean depth of 1.75 m (5.8 ft.)) allowed for a measureable release of both sensible and latent heat to the atmosphere. A land breeze was evident blowing to and across the lake from the north. When the breeze was in the vicinity of 2 knots, the temperatures downwind of the lake were 5° C (9° F) higher. When, however, the windspeed dropped to 0.5 knots, no temperature effect was noted downwind, although there was a build-up of warm air brought to the southern shore by turbulent diffusion. This type of occurrence—and the understanding of it—must be of considerable importance to growers in the mid- and south-Florida area during frost periods.
In the agricultural wetland area south of Lake Okeechobee, land is drained for farm use. It is highly organic peat and muck material which has a high heat capacity, especially when wet. This means it requires more heat to raise soil temperatures than mineral soils (e.g. sand). The heat conductivity of this soil is high when it is wet and low when it is dry. If the water table is lowered, the top layers dry out, their conductivity drops, they cool rapidly at night and the stored heat in the moist layers below cannot replace the heat loss in the upper layers. During periods of cold, there is a land breeze towards the lake, and the drained areas are at least 5° C (9° F) colder than the surrounding wetlands.

The drained lands are a double loss situation because during high temperature days when the sun is shining, there is considerable sensible heat moving downward through the ground. The latter type of transport accelerates the process of organic oxidation by solar ultraviolet rays, and consequently there have been tremendous soil losses since drainage has been in effect (1.25 inches per year during 1900—1955, a loss of about 40% of the volume of the better agricultural soils).

Ordinarily, under wetland or high soil-moisture situations, much of the quantity of energy going to the land is dissipated as latent heat to the atmosphere which process cools the land and air in contact with it. The rising vapor condenses above releasing the heat higher up, and thus allowing at least the vertical components of the type of circulation we have referred to. Soil moisture is therefore a very important factor in the process. The system is severely altered, however, in lands that are drained or capped with concrete. In such cases, most of the energy is absorbed and radiated back as sensible heat which fills the atmosphere in contact with the land and atmospheric layers above the lower layers. The vapor/condensation circulation is stopped or at least interfered with, and what results is called a ‘heat island’. These effects feed back into the mesoscale lake and sea breezes and alter their location and intensity. Since these systems are the primary organizing mechanisms (on undisturbed days) for the heat and moisture which fuel thunderstorms, the surface alterations merit serious study and concern (see Figure 8).
Figure 8 — Normal water cycle in south Florida and Heat island. (see text)
To come back to the major point, we need to consider once more the mesoscalar situation of the sea/lake breeze circulation. The circumstance with wetlands is essentially the same except that there are certain differences due to vegetation cover. Over a lake or wetland during the sunny days, energy taken up as latent heat causes vapor to rise high in the atmosphere and condense as clouds raining down again—theoretically a very local situation. With a sea breeze added to this, the vapor is pushed in the direction the breeze is going. In southeast Florida, the daytime sea breeze from the Atlantic, which may often be southeasterly, will push the rising water vapor from wetlands and lakes inland. How far inland depends upon the wind and the extent of the lake or wetland. On summer days late in the morning or early afternoon, one can see a line of cumulus clouds to the westward. In southwest Florida, the sea breeze from the Gulf of Mexico has a southward or southwest component. The cloudline is generated only a few miles inland. It is then moved toward the coast by the air aloft moving back over the ocean or Gulf. When the clouds formed by either system rain down, the circulation regime is completed as far as the water is concerned.

Another very important issue needs to be inserted at this point. The sea breeze from over the Atlantic (or Gulf), once initiated in the afternoon as a result of the heating patterns established over the peninsula, contains considerable moisture obtained during the sojourn of that air mass over the water. In fact the net gain in rainfall and ground water in south Florida is the result of this moisture being brought in. We know this because of trace amounts of sea salt present in the rainfall. To the moisture in this cooler air moving inland is added the water vapor from the wetlands and/or the lakes, about 35% of the total amount. Together they move both westward (or eastward from the Gulf) and upward to produce the cloudline then back aloft toward the coast. To really initiate and increase a vigorous sea breeze circulation, cumulus cloud growth must feed on the moisture already present in the lower atmosphere and that added due to evaporation. The essential character of both ingredients of the system can be depicted as follows.

During the mornings of sunny days when there are light winds, lakes
larger than 1 mile in diameter can give a visible positive influence to cumulus cloud formation. In afternoons or when winds are strong, the visible influence is not as great (unless lakes are much larger). In lakes and wetlands, under light winds, the clouds moving back toward the coast are anchored close to the drier land-water boundary. Though smaller scale systems, they are necessary ingredients in wetland areas.

The consequence of drainage of surface soil or coverage with concrete thus appears to be the retarding of evapotranspired water input necessary for the completion of our local or mesoscale rain cycle. It has been calculated that at present over south Florida, south of 27º latitude, human-made features or alterations retard as much water in one year from the evapotranspiration process as the combined volumes of Lake Okeechobee and the 3 water conservation areas. With insufficient input of water vapor into the rain cloud formation near the inland portion of the coast, the ultimate possible consequences are: the movement or retention farther inland of the rain clouds or less rain altogether either of which result in lower water levels in the Biscayne Aquifer (or other coastal aquifer), tendency toward desert formation, and a net increase in the heat island area and depth.

**PREPARATION FOR THE FUTURE**

It is evident that we are dealing with a balance of natural forces in direct personal involvement with south Florida residents. Certainly the effects are personal and can become apparent rapidly. It is not often, however, where it appears so clearly to be within the power of the residents to have such an influence on the outcome. Some obvious suggestions are ostensible.

1. The kind of meteorological research designed specifically to explain and predict the mesoscale effects from local environment alterations needs to be emphasized and supported. The federal government is involved via a number of grants; however, this involvement is primarily concerned with pollution transport and urban boundary layer effects. There is little being done on larger mesoscale domains such as penin-
sular Florida and the land-use changes resulting from drainage and megalopolitan development. Local government, industry, and the consumer public need to understand the situation which will affect the future of them all. Reference here is not to the quality of the water we consume but rather—first and foremost—the quantity. On a purely economic basis, the questions are what was, is, and will be the supply of water to the demands of a qualitatively and quantitatively changing population, and how, in data and informational terms, will a changing local weather pattern affect the water supply.

2. It is becoming more feasible to make general predictions on the type and magnitude of mesoscale climatological changes with numerical modeling and knowledge of surface properties. This is a necessary part of the knowledge of the water budget of an area contemplated for physical changes. This means a planned investigation of soil, heat, and moisture properties, properties of cultural features, vegetation, and water body dimensions with the outcome in the form of a testable model that can be used for impact prognoses. It can be accomplished by: 1) a systematic aerial sensing of soil moisture and other surface properties, and 2) utilization of combined high resolution mesoscale/cumulus scale models which can predict the entire cycle from sea breeze initiation through thunderstorm growth and decay.

3. A thorough investigation into previous circulation patterns and rainfall distributions needs to be made to establish a historic base. Some of these are available but need to be utilized in greater depth and with the type of techniques now applicable to meteorology. Local historic cultural alterations must of necessity be a part of such models. Much of this work is being accomplished at various government laboratories to study repeatable patterns and to plan weather modification. The current and near-future need of the results lies with those individuals and organization involved in the planning of the region's future.

4. The problem is of sufficient moment to set aside political and emotional factors in a sincere and cooperative effort to predict a very critical aspect of all of our individual and collective futures.
SUMMARY

1. The only significant natural flows to tidewater are in the southern tip of Florida in Everglades National Park and the eastern half of Big Cypress into the northwest portion of Everglades National Park. The coastal ridge water flow curves southwest into the Shark River Slough. All other natural flows are stopped or interfered with by the drainage or canal systems.

2. Water storage aquifers in south Florida are:
   Biscayne (southern Palm Beach, Broward, and Dade Counties)
   Southwest Florida (Collier Co. — thin to the west thick to the east.)
   Discontinuous, local, low yield (Lee, Hendry, and most of Palm Beach Counties)
   Coastal, moderate yield (Palm Beach and Martin Counties)

3. The soil-plant system filters water and chemically removes elements. Also, it controls evaporation and temperature of the ground and adjacent air layers.

4. Before 1900, south Florida was 75% wetland. Today, 35% of that wetland no longer exists due to drainage practices.

5. The annual rainfall of south Florida is about 60 inches of which 2/3 falls in the June to October period. The latter volume fraction is the result of mesoscale weather conditions.

6. Water can hold considerable heat (high heat capacity) and can later release it to the atmosphere — sensible heating. It does so slower and with less change in its own temperature than dry soil, peat, or muck. Thus it exerts greater control over the temperature of the environment. The same may be said of wet soil.

7. Some of the energy absorbed by water is used to evaporate it. The water vapor rises in the atmosphere; thus removing heat from the water surface. In the atmosphere, the vapor condenses to reform water. The removed heat is released there. Thus the energy originally absorbed is absorbed as ‘latent heat’.

8. Plants lose water as vapor in a biological process called transpiration. The amount of water lost as vapor to the atmosphere as evaporation and the amount lost by transpiration are measured as one process called evapotranspiration. The amount of water vapor contributed by each process can be considerable.

9. Evapotranspiration will increase with an increase in the amount of atmospheric heat radiation and with the speed of the wind. The latter itself is influenced by the shape and roughness of the terrain over which it blows. Evapotranspiration can be countered by increases in local humidity. Thus, general predictions, without taking local factors into consideration, can be contradictory.

10. The sea/lake breeze. During the daytime, the land and the air in contact with it becomes warmer than the water. The warmed air in contact with the land rises. Cooler air in contact with the water moves to position above the land — producing the sea/
lake breeze. Overhead, the rising warm air moves seaward to replace the air that was originally over the water. Thus a circulation is formed.

At night, the reverse occurs; i.e., the water surface is warmer than that of the land, and the air in contact with it warms and rises. Cooler air from over the land moves in to replace it, causing a land breeze. Overhead, the rising air moves towards the land producing a circulation opposite to that of the sea/lake breeze.

11. The land breeze system is much weaker than the sea/lake breeze system (there is no heat driving force — the sun — at night).

12. The sea breeze brings over the land water-saturated air (from the ocean or gulf). It hits the land, warms, and rises where the moisture condenses to form clouds.

13. Wetlands likewise are involved in formation of sea/lake breezes and form clouds from the moisture-laden rising air.

14. In south Florida, the sea breeze air from the ocean joins with the wetlands air to form the cumulus cloud line seen to the west of Miami in midday. In the afternoons, the clouds move towards the coast and rain down — thus completing the circulation pattern. In southwest Florida, the sea breezes have a westerly or southwesterly component.

15. If wetlands are removed, there are two consequences.

a. In order for rain to occur with any regularity, the moisture from the rising wetlands air (about 35% of the total) needs to be added to the sea breeze air (the net gain in rainfall is from this latter fraction). If wetlands near the coast are removed, the sea breeze cloud-forming air must go farther inland to receive wetland/lake moisture for rain clouds to form. Also the returning clouds are "anchored" to the wetlands-dry land border. Thus the rain may not get to the coastal area where the major human populations are located — as well as the aquifers.

b. When wetlands are replaced by structures or drained land, heat is stored and regenerated fast with no latent heat removal as water vapor. Not only the air in contact with the land heats up, but all the air above it. This columnar body of warm air interrupts or stops the breezes and creates a heat island.

16. Secondary consequences are: lowered water levels in coastal aquifers, salt water intrusion, increased heat island size, and tendency toward desert formation.
REFERENCES


We're Doing something about the weather, but sometimes don't realize it. Museum Magazine, II(9): 1980.


N.B. The reader’s attention is called to Geological Survey Investigation 1-850 and Professional Paper 1011. Many other pertinent articles and pamphlets are therein listed. They concern Florida resources and potentialities and are highly recommended.