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THE EVERGLADES: WILDERNESS VERSUS RAMPANT LAND DEVELOPMENT IN SOUTH FLORIDA[*]

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Imagine yourself in the midst of a flat, vast expanse of American wilderness. The shrieking sound of "kree-ah" "kree-ah" pierces the night air and you think of western prairies. But it is the limpkin's cry you hear, and the land surrounding you is under 4 feet of water—it is the sawgrass marsh community of Everglades National Park in Florida.

The Seminole Indians called the Everglades Pahayokee, or River of Grass. Everglades National Park is located at the mouth of this river, at the tip of the Florida peninsula. The park, the third largest in the country after Yellowstone and Mount McKinley, contains an abundance and variety of wildlife to be seen nowhere else in the United States. Perhaps most impressive are the anhingas, sometimes referred to as water turkeys or snake birds, and the large wading birds, including the roseate spoonbill, the great white heron, the wood ibis (actually a stork, the country's only stork), the white ibis, and the limpkin. So productive are the soils and the waterways in the park that these and over 300 other species of birds are supported here, in some cases in great density. Although the mammals, fish, and reptiles are somewhat more elusive than the large wading birds, they are no less exotic; such species as the alligator, the porpoise, the Virginia white-tailed deer, the manatee, or seacow, and even the rare panther, or mountain lion, find their niche in the Everglades ecosystem.

The plant communities too—such as the jungle-like hardwood forests, the cypress swamps, the sawgrass marshes, and the mangrove swamps—are unlike those found anywhere else in the United States. In short, the park is teeming with the plant and animal life of a tropical ecological community.

The park exists today because of the foresight of many individuals who, over the past decades, have loved the Everglades and fought to save them from destructive abuse by man. The National Audubon Society, which played a large role in establishing the National Park in 1947, is once again deeply engaged in the fight to save the Everglades. Over the years, the nature of the threat to the park has undergone a sinister evolution. Once it was hunters slaughtering egrets for their plumes, and alligator poachers satisfying the careless whim of the fashionable for alligator hide. The poaching still goes on today, unfortunately, and threatens the very existence of not only the alligator but also other species whose life cycle, we shall see, intertwines with that of the alligator. The new threat to the Everglades arises from activity which is not deliberately malicious, but is potentially more devastating because the technological arsenal man now employs in bending nature to his convenience is so formidable that the entire park is in the process of being overwhelmed. Although the fight to save the park is often joined, and rightly so, around such specific manifestations of that activity as the Army Corps of Engineers' flood control project or the proposed new supersonic jetport, the root causes lie deeper in the unrelenting pressure for growth in South Florida. We shall describe here the probable consequences of this pressure for the Everglades and for man himself. We shall see that the well-being of man and the park, in quite direct and material ways, are critically linked. In Part I we describe the Everglades ecosystem, emphasizing those features which render it susceptible to collapse. In Part II, we describe those present and proposed activities of man in South Florida which threaten the park's survival.

PART I. THE EVERGLADES

The profusion of plant and animal life in South Florida is only the more spectacularly visible part of an intricate and balanced ecosystem. What defines the Everglades and forges its unique qualities is the geology, the hydrology and the climate of South Florida and their interrelationships with the plant and animal life which flourish there. In order to comprehend the severity and extent of the threat to the park, it will be helpful first to understand more fully the Everglades ecosystem.

The park comprises 2,035 square miles of the southern tip of Florida. However, because the park is an integral part of a larger geological and ecological unit, it is misleading to talk about the park in isolation, and we must begin with a description of the entire region of South Florida.

South Florida did not always lie above sea level. Over the past hundreds of thousands of years the sea level has fluctuated in rhythm with glacial activity. As the glacial ice mass advanced southward, more of the sea's waters were locked up in the form of ice, and the sea level dropped; as the glacier retreated, the level rose. As a consequence, certain regions of the earth, including South Florida, were periodically submerged. During those periods in which the sea covered the land, a limestone deposit was continuously being formed on the floor of the sea, thus raising the elevation of the landmass. Now in a period of apparent glacial retreat, the sea level is rising.[1]

In addition, over the past few thousand years, fresh waters flowing southward from central Florida have deposited on the limestone base the silt that they were bearing, further extending the above-sea-level mass. This natural process is still probably continuing today, although its effects are dwarfed, as we shall see, by the influence of man on the balance between dry land and wet land in South Florida.

As might be expected from its geological history, South Florida is extremely flat. Within the boundary of the park, the land is never more than 10 feet above sea level. Only a slight ridge along the east coast, averaging 20 feet above sea level, disturbs the monotonous topography, and upon it squats the urban sprawl of greater Miami.

The same declination of the land which brought the silted waters southward from central Florida still exists today and is of profound importance to the park's ecology. This gentle slope, dropping on the average one inch per mile between Lake Okeechobee and the park, supports a surface flow of fresh water down to the southern regions of the park, where the fresh surface water merges with the salt waters of the Gulf of Mexico and Florida Bay. So gradual is this slope that it takes a drop of water on the average three months to complete the journey from the Lake Okeechobee region to the coast.

Of course, many things can happen to that drop of water to divert it from reaching the park directly. Under natural conditions it might evaporate, be transpired by a plant, or seep underground into semiporous rock layers, called the aquifer, where it then flows through natural underground channels to the sea. With man's presence firmly established in South Florida, the water might also irrigate a farmer's field and absorb a little DDT, cool an industrial engine, flush a toilet, or quench a human thirst. We shall be concerned in Part II of this essay with the magnitude and consequences of man's influence on water flow in South Florida.

Approximately 60 inches of rain a year falls on South Florida, which you might compare with the United States annual average of 30 inches. Very little of that water would remain on the land's surface were it not for the fact that something unusual has been occurring in much of South Florida over the past centuries. The passage of water downward from the surface into the aquifer is retarded in South Florida by a relatively water-impervious layer, called marl, which lies beneath the soil and is believed to be formed from the calcified remains of decayed algae and snails. Despite the fact that the algal mat grows abundantly along the floor of the Everglades marshes, marl formation takes place so slowly that little is actually known about the detailed process. In some areas the marl is as much as a foot or two thick.

We have seen, then, that South Florida can be thought of as a vast, shallow, slow-moving river, flowing from the headwaters in the Lake Okeechobee region south through the park and out into the Gulf; the region of South Florida between the lake and the northern park boundary thus serves as a huge watershed for the park.

However, this river differs in a number of respects from most rivers with which the reader is familiar. In most places it resembles more a marsh or a swamp than a river, for considerable vegetation protrudes above the water surface. Second, during a certain portion of the year much of the riverbed is dry; the area covered by water fluctuates enormously. This is because most of that 60 inches of rain, approximately 50 inches of it, falls between May and October, and thus there is a distinct dry season in the Everglades in the winter and early spring. Unusual adaptations of the wildlife to this cycle of wet and dry seasons, or hydroperiod, have developed, and we shall return to them shortly.

A variety of plant communities exist and compete in the park and in the inland regions north of the park; their characteristics are determined, to a great extent, by the hydrological and geological factors we have just discussed and, in addition, by the warm temperatures which average 68° in winter and 80° in summer.

In the eastern portion we find the true "Everglades," which is sawgrass marsh. Resembling somewhat a Kansas wheat field under several feet of water, the sawgrass marsh expanses are interrupted only by stretches of pine forest and tree islands or hammocks. Hammocks form either on naturally occurring higher ground where the marl is thicker and higher than in the surrounding marsh or on depressions in the marl in which decayed plant material accumulates around the roots of small plants and becomes peat, thus allowing the transition to larger plant forms.

Hammocks consist typically of large stands of tropical hardwood trees, such as the mahogany, a variety of palms, the coral bean, the gumbo-limbo, and a number of northern trees, including mulberries, oaks, and maples, which grow here at the southern limit of their range. Along the forest floor of the hammocks grow abundant ferns, orchids, ivies, and fruit-bearing shrubs; a hammock is truly a jungle of plants. The pine forests and hammocks provide for wildlife the high ground and protective cover needed for nesting.

Fires have undoubtedly influenced the pattern and growth of hammocks and sawgrass in the Everglades since Indians inhabited the area. An interesting and plausible hypothesis concerning the role of fire has been suggested by the ecologist Frank Egler:

> In the sawgrass country, the tangled herbaceous vegetation is ready to burn even before the soil is dry, while there may still be a few inches of water on the surface. Assuming that Indians were free and careless with fire, it follows that more often than not the fires would get started at the inception of the dry season in fall. In this manner, the fires would skim over the surface, not damaging the water-covered roots. The fires would smack against a dense hammock, and stop, pronto. The hammock itself may be under water; the foliage would be turgid and fire-resistant. Then, at the end of the dry season, when the peat soil and the hammock trees actually could burn, then there was no sawgrass debris on the surface with which a fire could get started. It is only by this hypothesis that I can logically account for the wall-like abruptness of the hammocks, existing quite paradoxically as dryseason-burnable islands in a sea of burned vegetation which sea, without the burning, would quickly be invaded by those same hammock trees.[2]

The role of fire may be changing. According to Egler:

> The chief difference between Indian fires and whiteman fires: Indians burned with no conscience, as soon as things would burn. Whiteman, with a conscience, only delays burning, and when the vegetation does ignite, it creates a conflagration undreamed of to the Indian.[3]

Of course, even before man inhabited the Everglades, lightning fires must have had their impact on vegetation patterns in the region.

In order to convey some impression of the richness of life in the sawgrass marsh, we can compare the "net primary productivity per unit area" of various ecological communities. This quantity is defined as the number of dry grams of green plant matter produced per square meter per year, and in the sawgrass marsh averages about 2,000. In comparison, in a temperate zone forest, in a Colorado pasture, and in a desert, the typical values are 1,500, 500, and 30, respectively. For the entire earth, the average is 320. Only the oceans' estuaries, tropical forests, and farmland managed scientifically, compete with the marsh community in their net primary productivity per unit area.

Moving across South Florida to the west, in inland Collier County, and not within the boundaries of the park, one finds the Big Cypress Swamp. Here, several decades ago, grew the most magnificent cypresses in the country, often so big that three men could not reach around the trunk. Now few of these giant trees remain, thanks to an unregulated timber industry. Despite this loss, the cypress community is still a vital component in the ecosystem of which the park is a part, and, in its own right, it is a strange, lovely wilderness. Many of the large marsh birds which, during certain times of the year, reside in the park feed and nest in the Big Cypress Swamp. In fact, a number of birds and mammals inhabiting the Big Cypress area for part of the year are on the Bureau of Sport Fisheries and Wildlife list of rare and endangered species in the United States. Among these are the wood ibis, the roseate spoonbill, the southern bald eagle, the Cape Sable seaside sparrow, the panther, and the alligator. By providing a congenial breeding and feeding environment, the Big Cypress Swamp serves to make their existence less precarious. Moreover, being upstream from the park, the cypress swamp is a vital part of the watershed from which the park derives its overland flow of water.

Moving southward, as you approach the Gulf Coast estuaries or brackish zones, where fresh water and salt water meet, the sawgrass and cypress communities give way to dense labyrinthine mangrove swamps. Mangrove trees grow in the semisaline waters of the estuaries as well as farther out in the shallow waters of the Gulf. The red mangrove, one of the species found in the park, propagates by dropping into the water seedlings which have already formed a simple root system while growing on the parent. These seedlings then float until they reach sufficiently shallow water to form a roothold in the muck. So numerous and intricately connected are the mangrove clusters that the result is a living maze of narrow waterways in which canoeists can become lost for days.

The estuaries are the nurseries of the sea; in them many of the oceans' fishes, crustacea, and other forms of sea life spawn and feed. In particular, the park's estuaries support the porpoise, the manatee, a large number of game fish (including the redfish, the barracuda, and various species of trout), and the large Tortugas pink shrimp. The shrimp breed in these estuaries and then are caught off the Dry Tortugas, islands west of Key West; they are of major commercial value in South Florida. These and many other forms of marine life, especially those lower down the food chain, are quite sensitive to the salinity of the water. If insufficient fresh water moves through the park and out into the estuaries, then oversalination occurs.

The seasonal variation in the rainfall, we noted, gives rise to a seasonal variation in the amount of fresh water which flows overland down through Collier, Dade, and Monroe countries and into the park. Whereas in the late summer the sawgrass community in the park may have been submerged under a depth of up to 3, 4, or even 5 feet of water, in the late winter (there is a time lag of approximately three months) the water level often drops to the point where much of the land is dry. How then do the animals survive the dry period? The alligator, it seems, is the animal which saves them.

All through the Everglades one finds depressions in the sawgrass marshes; these depressions measure anywhere from 10 to 100 feet in diameter and are typically several feet deeper than the surrounding marsh. Alligators actually scoop out these depressions with their tails, seasonally maintaining them against the leveling forces of the water. It is part of the mystery of the Everglades, however, that the origin of these depressions is unknown. In these depressions, known as alligator holes, scarce water collects and forms pools during the dry season; as a result, the aquatic and semiaquatic forms of life such as plankton, crustacea, fish, frogs, snakes, turtles, marsh birds, and, of course, the alligator have enough water to survive.

In fact, some species not only survive but with an apparent manlike obliviousness to their environment, choose to reproduce during the dry season and thus place the greatest demands on the food supply at this critical time. The wood ibis is a good example, for this bird can catch food efficiently only when its food supply is concentrated. Let us share J. J. Aubudon's keen observation:

> This species feeds entirely on fish and aquatic reptiles, of which it destroys an enormous quantity, in fact more than it eats; for if they have been killing fish for half an hour and have gorged themselves, they suffer the rest to lie on the water untouched, when it becomes food for alligators, crows, and vultures, whenever these animals can lay hold of it. To procure its food, the wood ibis walks through shallow muddy lakes or bayous in numbers. As soon as they have discovered a place abounding in fish, they dance as it were all through it, until the water becomes thick with the mud stirred from the bottom by their feet. The fishes, on rising to the surface, are instantly struck by the beaks of the ibises, and, on being deprived of life, they turn over and so remain. In the course of 10 or 15 minutes, hundreds of fishes, frogs, young alligators, and water snakes cover the surface, and the birds greedily swallow them until they are completely gorged, after which they walk to the nearest margins, place themselves in long rows, with their breasts all turned toward the sun, in the manner of pelicans and vultures, and thus remain for an hour or so.[4]

We can thus understand why the dry season in the Everglades is the propitious season for the wood ibis to nest; his groping method of food procurement can provide the large quantities of food needed in the nesting season only when the food supply is highly concentrated in the alligator holes.

One can think of the Everglades hydroperiod as a two-cycle engine; in the wet season there is a tremendous growth of purely aquatic life, and in the dry season there is a concentration of it. This cycle of production and concentration of aquatic life then affects the life cycle of the semiaquatic forms of life.

The success of these adaptations to the hydroperiod depends on adequate amounts of water flow into the park from the north. The rains cease in September, usually, but the surface flow continues on into the early winter and thus shortens the effective dry season from six months to more like two to four months. The best estimate is that 80 percent of the park water arrives in the form of rain falling directly on the park and only 20 percent flows into the park from the north, but nevertheless that 20 percent is crucial if the alligator holes are not to dry up. In addition, a certain minimal amount of moisture in the top layers of peat around the sawgrass roots is necessary to protect the peat from the periodic fires, mentioned above, which would otherwise do long-range damage to the viability of the sawgrass community.

The health of the park is as sensitive to variations in water *quality* as it is to the quantity and timing of surface water flow southward into the park, for the animals and plants in the park depend upon exceptionally pure water. Throughout most of the park, except, of course, in the brackish estuaries and the Gulf, the surface water is safe for human consumption. In fact, purer water is required by several species of the minute plankton at the beginning of the food chains than by man or the other higher animals at the top of the food chains.

Three prime sources of water pollution in the Everglades are agricultural fertilizers, urban and industrial sewage, and persistent chemical pesticides such as DDT. If runoff water carries nutrients from the farmers' fields or from sewage into the waterways of the Everglades, a bloom or rapid growth of vegetation may result. This phenomenon of increasing fecundity of water is called eutrophication, and its effects may be seen in the Shark River Slough in the park, where there have been algal blooms in recent years. This has led to an unnaturally rapid filling in of the waterways and alligator holes and thus to a loss of aquatic habitat.

Nitrogen and inorganic phosphorus are the primary nutrients that are responsible for eutrophication. Average levels of concentration of these nutrients are measured as ratios of the weights of nitrate ions (NO_3) and of phosphate ions (PO_4) to the weight of the water sample in which they are found. In the Everglades, the concentrations are 1.5 parts per million (ppm) and 0.1 ppm respectively. By way of comparison, secondary treatment applied to the waters used in the residential areas in South Florida results in treated water with concentrations of 20 to 30 ppm and 1 ppm, respectively. The treated sewage of the population centers in South Florida may present a potential hazard to the Everglades ecosystem if it is allowed to flow into the park's waters.

Persistent pesticides find their way to the Everglades because of their heavy use on citrus and vegetable farms and on lawns and home gardens in South Florida. In the Everglades and in Florida Bay the effects of this contamination on the bald eagle and the brown pelican populations have been especially severe in recent years. The biological magnification of DDT concentrations as the pesticides move up through the food chain is documented in Table 1 which gives the present levels of persistent pesticide in selected components of the Everglades ecosystem.

As we have seen, the cycle of animal life in the park has evolved so as to be in rhythm with the hydroperiod. This adaptation has developed over millenia. The diversity of species and the complexity of the interrelationships among them reflect a viable natural community—one which has evolved into an equilibrium situation which is stable against naturally occurring variations in the environment, such as the hydroperiod. However, since this stability has been achieved by means of the rather specialized adaptations of many of the park's species to the hydroperiod, any severe alteration in the water cycle can threaten the survival of the park.

TABLE 1

CONCENTRATION OF DDT, DDD, AND DDE

Component	Sum of DDT + DDD + DDE in parts per billion
Fresh and estuarine water	0.02
Rainfall	0.08
Marsh soil	40.00
Algal mat	200.00
Small fish	500.00
Bald eagle	8,000.00
Brown pelican	8,000.00

Source: Adapted from The National Academy of Sciences, report, Washington, D.C., 1970.

Thinking back over what we have described, the algae and the marl, the alligator and the ibis, the salinity of the estuaries and the shrimp, we see these adaptations, cycles, and intricate interrelationships of all forms of life as a source of wonder to man; they are also an intimation of the catastrophe that may occur if man tampers with the natural forces that have forged them.

Part II. Threats to Man and the Park

The future health of Everglades National Park will be seriously affected by any major new international jetport built in South Florida, especially if it is located near the park. In 1968 the Dade County Port Authority purchased 39 square miles of land in the Big Cypress Swamp for a new jetport; the southern boundary of the property lay only 7 miles north of Everglades National Park. The National Audubon Society and other conservation organizations challenged the Port Authority at a series of hearings, and secured dramatic and favorable coverage of the jetport controversy in the national news magazines and on television. As a result of the efforts of these conservationists, the Department of Interior, the National Academy of Sciences, and a private group headed by former Interior Secretary Udall, investigated the jetport during the summer of 1969. All three produced reports that expressed alarm over the likely impact of the jetport on the National Park. All the while, the Port Authority was constructing a 10,500-foot runway at the site. During the autumn of 1969, the Nixon administration, asserting that the time had come for a new commitment to environmental quality in America, announced the decision that the development of a commercial jetport at the Big Cypress Swamp site was too severe a threat to Everglades National Park to be permitted to occur. The press wrote colorfully about the confrontation between the bird and the plane, and there were headlines like "Against all odds, the birds have won."

In this section, we shall first review briefly some of the issues that surrounded the jetport controversy. Then we shall describe in somewhat greater detail the way in which Everglades National Park is endangered by development north of the park in the southeastern and southwestern parts of the state. The victory of the conservationists on the jetport issue was substantial, to be sure, but many more battles will have to be fought before the park has secured its vital supply lines, above all those which must bring it sufficient water of high quality.

Issues in the Jetport Controversy

The case for further airport facilities in South Florida has usually been considered a strong one. In 1968 Miami International Airport, the airport now handling the major commercial flights to South Florida, handled 445,000 operations (takeoffs or landings), which made it the eleventh busiest airport in the United States.[5]

The present airport cannot expand, for it is virtually surrounded by urban development; the city of Miami, spreading inland from the coast, has engulfed it like an amoeba eating a food particle.

One-fourth of the operations at Miami International in 1968 were not commercial flights at all, but training flights for pilots and crews. The Nixon administration decision which had banned the development of a commercial jetport at the Big Cypress Swamp site explicitly authorized the site to be used for training operations for three years.

New commercial flights into Miami International are likely to replace the training flights as they are moved, and the Dade County Port Authority has claimed that additional facilities must be developed immediately to deal with the situation when Miami International is again saturated. It is easy for the Port Authority to find data which show that tourist and business travel by air has increased steadily in recent years; it is then a simple matter to "predict on the basis of past trends" that the traffic will keep growing. If this is coupled with a sufficiently intense advertising campaign in the colder climates, it is possible that these predictions will come true.

Greatly expanded air traffic facilities represent a threat to the natural environment of South Florida quite generally, as well as to Everglades National Park. The most serious environmental problem of Miami International Airport—noise—will be diminished if some traffic is transferred to less populated areas, but there will always be some people under every new flight corridor. Indeed, the Big Cypress Swamp site, which was chosen in part because it was a full 40 miles from the dense population concentration of Miami, is only 5 miles from a quarter-mile wide strip of land that is the reservation of the Miccosukee Indians. Moreover, the training flights now using the Big Cypress Swamp site pass over Everglades National Park, so that planes are intruding on the wilderness experience of park visitors. The concept of a wilderness experience was purposefully included in the act which established Everglades National Park, and this concept is being eroded.

Air pollution is another hazard of expanded air traffic in South Florida, no matter where an airport is built. Air pollution patterns from jetport operations are qualitatively different from the patterns resulting from ground-level sources. At increasing distances downwind from a highway, for example, the pollution levels drop rapidly because the dirty air undergoes vertical mixing with uncontaminated air above it; downwind from a jetport, however, the pollution levels will drop much more slowly, because the higher air will be dirty too, having received contaminants from descending and climbing aircraft. Because all planes take off and land in the same narrow east-west corridor, air pollution is confined to a strip roughly 2 miles wide and 20 to 40 miles long. Within this strip a jetport handling one million operations per year will produce levels of oxides of nitrogen estimated at twenty-millionths of a gram per cubic meter of air, over and above whatever oxides of nitrogen are produced in the strip by ground-level sources like automobiles. This level is comparable to present average nitrogen oxide levels due to all sources in Washington, D. C. (ten millionths of a gram per cubic meter). Jetport air pollution has never been investigated extensively, in part because most major airports are near industrial cities which mask the effects, but it is a serious question in South Florida, where considerable effort has been spent on keeping air quality standards high.

Expanding the use of South Florida for *international* air travel poses a special set of problems, following from the necessity to maintain the highest health standards at a location where passengers disembark from trips all over the world. Insects capable of carrying many serious virus diseases are found within Everglades National Park, and to a lesser extent, in the water conservation areas. If an insect were to bite a passenger who was ill with a disease for which that insect was a vector (the technical word for "potential carrier"), the insect would become a carrier and the disease would be transmitted to the next person whom that insect attacked. There is something reckless, from a public health viewpoint, about locating an international airport in the vicinity of the park or of any other tropical wilderness where dangerous insect vectors are found.[6]

If an international jetport is built anywhere near the park, one can anticipate a major program of spraying with insecticides. World Health Organization standards require daily spraying with DDT within and even beyond the boundaries of any international jetport. Even if the standards are changed to allow the use of biodegradable pesticides, such a program would have serious ecological consequences for the park. These "pests," after all, are part of the Everglades food chain.

It is clear that the direct effects of a new jetport, which we have just outlined, will be deleterious for the human populations of South Florida as well as for the plant and animal populations of Everglades National Park. However, the most serious effect of a new jetport will be an indirect one. A new jetport will act as a stimulus to the further development of the South Florida economy, first of all in the immediate vicinity of whatever site is chosen, but also more generally throughout the region. When we now turn to the larger issues related to economic expansion in South Florida, we shall discover a similar confluence of interests: For the park to be protected, development must be restricted, and land use must be carefully planned; the same restrictions and plans are in the best interests of those who wish to see the optimal orderly development of South Florida.

Competing Demands for Water in Southeast Florida

North and east of the park, three of the most rapidly growing counties in America—Dade, Broward, and Palm Beach counties—are found. A narrow strip along the Atlantic coast includes the cities of Miami, Fort Lauderdale, and Palm Beach, which have been nearly fused together by additional settlement between them. Dade County, which includes Miami, more than doubled its population between 1950 (when it had just under half a million people) and 1968 (when it had more than 1.1 million people).

Land development in Southeast Florida is confined to a narrow coastal region by deliberate policy. Today, if you own land twenty miles inland from Miami, your land would lie under water for much of the year, and would be located within a Water Conservation Area administered by the Central and Southern Florida Flood Control District. The District, as a result of having purchased legal rights, known as water easements, has the exclusive right to determine what happens to the water in the

Water Conservation Areas. To build a house on your land, unless you intend to put it on stilts, you would have to dig a drainage ditch to get the water off your property, and that is just what the Flood Control District will not permit you to do.

Your land, with the water sitting on it, is worth a great deal to South Florida. The Army Corps of Engineers in the last 25 years has built a complex network of canals, levees, and sluice gates that lace the eastern half of southern Florida like an old-fashioned corset. As a result of these structures, which the Flood Control District administers, water can be moved out of Lake Okeechobee and onto your land to reduce the danger of flooding near the lake in the hurricane season. The District can also move water off your land in the growing season to supply a citrus grower with irrigation. The District can let the water simply stand on your land, in which case your land is functioning as a water reservoir for the urban coastal populations; the water on your land is then also helping to keep the salt water in the ocean from invading the coastal water supplies. Or the District can, in the appropriate or inappropriate season, move the water southward from your land through one of several big sluice gates and into Everglades National Park.[7]

From the point of view of the park, it is clear that it makes all the difference in the world which option the Flood Control District chooses. If the Flood Control District wants to, it can close the big sluice gates and no water at all will flow into the park from the Conservation Areas. This indeed is what happened for five years, from 1961 to 1965, with considerable damage to the park. In those years the rainfall was a few inches below normal, and water appeared to be in short supply; the cities and the agricultural interests got all the water they needed, but the park got nothing.

What will happen if the population of South Florida keeps growing? There will come a time, perhaps within this decade, when the choice again will be between a water shortage in Miami, a lower yield in the orange groves, and dried-up water holes in the Everglades. At first the choice will have to be made in the dry years only, and the Flood Control District will be able to take care of two out of the three demands. Later, the choice will have to be made in the wet years also, and the Flood Control District (if, as one would expect, it puts the urban needs first) will not be able to meet either the farmers' needs or the park's needs.[8] Eventually, there will not even be enough water for the urban population without greatly enlarging the region from which the urban needs are supplied. People scoff at such remarks, especially if they have seen the water standing on the land in the Everglades. But the fact is that the Flood Control District has to go further away every year to obtain water for the cities.

Obviously, a water supply can be expanded if water is used more than once, irrigating fields with the waste water from the cities, cycling bathtub water into air conditioners, and so forth. However, multiple use only makes sense if each successive use makes less severe demands on water quality, or if water is treated between uses, because in each use the water quality deteriorates. What this means is that without special water treatment plants the park cannot effectively share water with any other user, because, as explained in Part I, the park requires water of an even higher quality than that required for public water supplies. In a sense, the water that irrigates a farm in the rapidly expanding agricultural area around Homestead and then drains into the park a few miles south *is* being used twice, but the second use, as the water enters the park laden with nitrates, phosphates, and pesticides, is as a poison! A serious threat to the park, perhaps no less significant than the reduction in the quantity of water flowing into the park, is the debasement of the quality of that water.

In summary, it is already time to regard fresh water as a scarce and precious resource in South Florida not only for the park but also for the people. The existence of a Flood Control District permits comprehensive planning to determine water use in Southeast Florida, provided that there is some restraint on coastal development. The demands of Everglades National Park for water are substantial; they are equivalent to the demands of three million people. Whether these demands are reflected in the planning which is done depends most of all on how highly the people of Florida value the park. But if coastal development is not curtailed, someday soon the best intentions will not be enough to give the park its water.

Through its appropriations to the Army Corps of Engineers, the federal government has some leverage on how the Flood Control District apportions its water. In legislation signed into law in June 1970, concerned members of Congress were able to include quantitative guidelines relating to the obligations of the Flood Control District to the national park:

> Delivery of water from the central and southern Florida project to the Everglades National Park shall be not less than 315,000 acre feet annually, prorated according to the monthly schedule set forth in the National Park Service letter of Oct 20 1967 to the Office of the Chief of Engineers, or 16.5 per centum of total deliveries from the project for all purposes including the Park, whichever is less. (Public Law 91282, Section 2)

Even minimal legislation of this kind can be enforced only if coastal development is restrained. Otherwise, even the best intentions will not suffice to give the park its water. Implicit in the development plans for Florida's east coast are life-and-death decisions for Everglades National Park.

Potential Chaos in Southwest Florida

As we have just seen, the storage of water in the inland water conservation areas in the eastern half of the peninsula provides a reservoir of water for the coastal populations and also keeps the ocean's salt water from contaminating the coastal water supplies. We, the authors of this essay, happen to have studied the issue of future land development in the relatively unpopulated *western* half of the peninsula when we participated in a study of the Everglades during the summer of 1969 held under the auspices of the National Academy of Sciences and the National Academy of Engineering. The National Academy study group asked itself the question: Are the same water conservation practices going to be necessary in the western half of the peninsula as in the east? After exploring this question for a month, we became convinced that the Big Cypress Swamp, roughly coextensive with the eastern half of Collier County and the part of Monroe County north of the park boundary, has a hydrological function in southwestern Florida which is quite analogous to that of the water conservation areas in southeastern Florida.

Why should we have become interested in this problem? The jetport controversy originally stimulated our investigation, because rapid land development is being forecast for Southwest Florida, and the jetport would have encouraged this development.[9] Land development and extensive drainage of the Big

Cypress Swamp, we realized, would have a disastrous impact on the water supply to the park. Moreover, we suspected that it would also have a disastrous impact on the water supply available to the residents of Southwest Florida.

In order to start thinking sensibly about water management, we had to know how the water moves underground in the porous rock formations known as aquifers. Fortunately, the U.S. Geological Survey has described the aquifers in southeastern Florida and in southwestern Florida in two recent reports.[10] The information about the southeastern aquifers is quite complete; the information about the southwestern aquifers is more scanty, but it is adequate for a crude assessment of the problem.

The peninsula of southern Florida can be considered to be approximately symmetrical in that the eastern half resembles the western half. It turns out that this symmetry not only applies to the configuration of the land above sea level, but also applies to the underground aquifers. South Florida has two major aquifers: one east of the middle line, one west of it.[11] Both aquifers are made of limestone, and both have the shape of a wedge, a few feet thick near the middle of the peninsula (the two aquifers almost join one another, but not quite), 100 feet thick at the respective coasts. Because one continuous aquifer runs from mid-peninsula to the coast, tampering with the aquifer inland will inevitably have consequences at the coast.

The western aquifer, however, is of lower quality than the eastern aquifer in several respects: (1) The water in the western aquifer is more highly mineralized than the water in the eastern aquifer. There are several locations on the west coast where the water drawn up from wells has been found to be barely drinkable. (2) Rainwater does not seep down to the western aquifer as easily as it seeps down to the eastern aquifer (as hydrologists would say it, the recharge rate is lower). (3) Less water can be stored in a cubic foot of the western aquifer than in a cubic foot of the eastern aquifer (as hydrologists would say it, the storage capacity per unit volume is less). (4) Water pressure is not transmitted as easily through the western aquifer (the average transmissibility is less).

These differences tend to make even more severe the adverse consequences that will result if the inland water is drained off the land in the west. If less rainwater reaches the aquifer, the salinity of the water supply will increase. Since the capacity of the aquifer is smaller, the same amount of drainage means a larger percentage change in the water stored. And the pressure due to the higher water inland is more essential to drive the water through the aquifer when the transmissibility is lower.

To drain the land means to channel enough of the rainwater away from the land so that the upper surface of the standing water, the water table, will not rise above ground at any season of the year. This can be accomplished by digging canals to guide the water off the land, but because the land is so flat, pumps may be required as well. And, in this flat land, there may be nowhere else to drive the water except into the sea.

Once the water table is lowered, the volume of water stored is reduced. Nothing could be simpler. In principle, the process is reversible: close off the canals, and within a few years the water will again cover the land. In practice, drainage is one of the least reversible steps that men can undertake, for on drained land men will build houses and farms, and who then will say, let the water return?

The lowering of the water table inland will decrease the volume of the potential water supply for the west coast residents. In addition, if the water table is lowered, salt water from the sea will invade a larger portion of the aquifer under the land, so that, unless a well near the coast is very shallow, the water it will bring up will be contaminated. Thus, where fresh water is at a premium, drainage of the natural inland reservoirs lowers the limit on the largest population which the area can sustain. The reason one has not heard this argument in most of the United States is that population densities are rarely as large, and watersheds as small, flat, and nearly surrounded by sea water as in the narrow South Florida peninsula. One similar region is Long Island, New York.

The reason why salt water invades fresh water is easily explained. To begin with, ask yourself whether a well dug near the ocean shore will encounter salt water or fresh water. The answer turns out to depend on how deep the well is and how high the water table is where the well is being dug. A simple model will tell us where the salt water leaves off and the fresh water begins.

Water permeates any porous subsurface rock, and moves within it. This is just as true for the sand and limestone beneath the ocean as for the soil and limestone beneath the land. Water in either case keeps on seeping downward until some kind of impermeable rock is encountered; on the two coasts of Florida, this is roughly one hundred feet below sea level. In the permeable rock under the ocean, far from the coast, we find salt water, and in the permeable rock under the land far from the coast we find fresh water which has earlier fallen as rain. But near the coast there must be a combat zone.

If salt and fresh water had the same density, the combat zone would lie directly beneath the shoreline. But, in fact, salt water is two and one half percent heavier than fresh water (i.e., its density is 1.025 gms/cc.). Accordingly, beneath a column of salt water, the pressure is 2.5% greater than beneath a column of fresh water of the same height. So, right at the coast, where the water table must be at sea level, if one started with a column of fresh water beneath the shoreline, it would literally be pushed inland by the sea. Hence the combat zone is under the land.

The only thing which finally stops the salt water is the fact that away from the coast, the water table has a chance to rise above sea level, and thereby the fresh water has a chance to build up extra pressure. Below any point on land, the boundary between the fresh water and the salt water occurs where the fresh water depth (measured from the water table) is just two and one half percent greater than the depth below sea level. At that depth, the pressures of the salt water column and the fresh water column are equal. The fresh water column is 1.025 (or 41/40) times as high as the salt water column.

Thus, near the coast, one will find 40 times as much fresh water below sea level as above sea level in the aquifer. For example, if the water table is 2 feet above sea level the boundary salt and fresh water will be 80 feet below sea level.

Accordingly, the boundary surface which marks the furthest advance inland of the ocean waters reflects the shape of the water table like an elongating mirror. Of course, in practice the boundary between salt and fresh water is not sharp, but the transition zone of intermediate salinity is actually quite well defined, and this crude model is reasonably accurate.

If the water table is lowered anywhere between the coast and that inland region where fresh water is found all the way down to the impermeable rock, there will evidently be increased salt intrusion. Inland drainage where the land is as flat as in South Florida, will lower the water table over large distances, not just near the drainage area.

As drainage begins in the west, the first evidence is appearing of the contamination of coastal water supplies by sea water. A similar problem had arisen years before in the eastern part of the peninsula: inland drainage for the purpose of establishing agricultural land led to the intrusion of salt water into the coastal water supplies near the drainage outlets, the Miami River and the Tamiami Canal. As a by-product of having established the water conservation areas and having closed off these canals, the east coast aquifer has been flushed out again, but the process took many years.

One of the problems with salt water intrusion is that it is difficult to establish whose drainage program has contaminated whose water supply, and hence the law is almost helpless to deal with the individual case. What is required, instead, is an overall plan. Two possible plans, at two extremes in terms of population distribution, are: (1) The Big Cypress Swamp can be drained and settled, with the total population in fact limited by the available water supply, or (2) The Big Cypress Swamp can be left in its natural state, much of it flooded much of the year, with the population confined to a coastal strip.

The first option, draining the Big Cypress Swamp, would deprive the park of thirty to forty percent of the surface water which it receives from the north. The development which would follow on the drained land would add problems of pesticide and nutrient contamination. The park, in all probability, would be devastated. The Big Cypress Swamp, itself a marvelous wilderness teeming with animal life, would vanish. And, in addition, the diminished volume of water stored in the inland aquifer and the intrusion of seawater into the coastal aquifer would seriously impair the water supplies of the coastal residents. Small wonder, then, that the National Academy of Sciences report argued for the *second* option:

> Our most important specific conclusion is that maintenance of a large portion of the Big Cypress Swamp as a natural water-conservation area would serve several useful purposes simultaneously, with respect to preservation of the Everglades Park and to an orderly development of Southwest Florida, as well as preservation of the Big Cypress wilderness itself.[12]

Because the western aquifer is less plentiful than the eastern aquifer, even with the second plan populations will be water-limited at levels substantially below those obtained on the east coast. A large west coast population will also have to contend with the shallowness of the Gulf of Mexico, and its slow flushing rate; it will be a struggle to keep the Gulf healthy, if it is overused for sewage. Moreover, the extraordinary beauty of the west coast today will only be preserved if aesthetic considerations play a major role in determining whatever coastal development does occur. But with the Big Cypress Swamp preserved as a natural water conservation area, at least the problem of salt-water intrusion should not arise.

Options for the Future

To preserve the Big Cypress Swamp requires money, for the land is now privately held, and if it is to be permanently set aside it must be purchased by the state or federal agency that will administer the land. We are talking about at least half a million acres at $100 to $200 per acre. Such sums could be threshed out of the many times larger profits which those who are involved in the development of South Florida will harvest in the next decade.[13] If the Big Cypress Swamp is not purchased and set aside, federal land reclamation (that is, drainage) projects costing hundreds of millions of dollars will probably be undertaken at the taxpayer's expense. The immediate necessity is to buy time, so that drainage does not begin precipitously.

Fortunately, some time has been won by a decision of the Collier County government not to permit any changes in the zoning regulations in the eastern half of the county for a two-year period ending in October 1971. Since all of that land is currently zoned for agriculture, this effectively prohibits the formation of large-scale drainage projects, which only developers of major industrial or residential properties are prepared to undertake. In principle these zoning regulations could be extended indefinitely. In fact, when we talked with Collier County officials in January 1970, we were disturbed to find that these county zoning ordinances were regarded with distaste and with embarrassment. We heard several times, as an accompaniment to the phrase "you can't stop progress," the phrase "a man has a right to develop his land." Here was the ethic of rugged individualism, being transplanted to a situation where the individual landowner is a land speculator living somewhere remote from Florida (in some cases, Brazil or Japan), who, by checking the appropriate box in a printed inquiry, will permit some major land developer to go in, drain the land, and then sell the land for him. A man has a right not to have his property confiscated without compensation, to be sure, but does he really have a right to *develop* it?

We heard these phrases from a man of considerable authority, who also confided in us: "I'd personally just as soon see our county stay just the way it is right now, but you'll never catch me saying that in public." The odds are that in South Florida the god of unrestricted economic growth will continue to be obeyed, not challenged, until it is much too late. The Everglades Park will be ruined, and one can then drain it and pave it over as well. With the estuaries destroyed, there will be no fishing because there will be no place for the fish to breed. With no aquatic life to worry about, thermal pollution of Biscayne Bay, Florida Bay, and the Gulf becomes less troublesome, and so one could desalinate immense quantities of seawater and service maybe twenty million people living on quarter-acre plots across the whole of South Florida. The air would probably not be as bad as in Los Angeles, the traffic might not be as bad as in New York. Man would have subdued the River of Grass and eradicated that most offending of all the useless offspring of nature, the swamp.

Or, it is just barely possible, there will be another outcome, and our grandchildren will be able to see an anhinga.

FOOTNOTES

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[1] Estimates are that the present rate of rise is 2½ inches per century.

[2] Frank E. Egler, "Southeast saline Everglades Vegetation, Florida, and Its Management," *Vegetation*, Vol. III, p. 213 (1952).

[3] *Ibid.*

[4] John James Audubon, Ornithological Biography, Vol. III, Edinburgh: Adam and Charles Black, 1835.

[5] The airports that ranked ahead of Miami International were only slightly busier, for O'Hare in Chicago, the busiest of them all, had 691,000 operations. Since there are 525,600 minutes in a year, all of the major airports handle approximately one operation every minute.

[6] The discussions of jetport air pollution and of insect vectors follow closely the discussion in Sections 4 and 5 of "Environmental Problems in South Florida," published by the National Academy of Sciences, Washington, D.C., 1970.

[7] The park has been used as a dumping ground for excess water in times of unusually heavy rainfall, when there has been flood danger to the north.

[8] The farmland may disappear anyhow, because property values are rising to the point where other uses of the land seem financially more attractive.

[9] The plans for the jetport had already stimulated land development even before the jetport began its first operations: Land was sold in the Big Cypress Swamp at around $150 per acre in 1961, but at about $450 per acre in 1968, after the jetport site had been selected. These prices refer to comparable land, located in the interior of the Big Cypress Swamp in areas inaccessible by road at the present time.

[10] Melvin C. Schroeder, Howard Klein, & Nevin D. Hoy, "Biscayne Aquifer of Dade and Broward Counties, Florida," Report of Investigations No. 17, Florida Geological Survey, Tallahassee, Florida, 1958; H. J. McCoy, "Ground-Water Resources of Collier County, Florida," Report of Investigations No. 31, Florida Geological Survey, Tallahassee, Florida, 1962.

[11] The eastern aquifer, in the Geological Survey reports, is called the Biscayne aquifer, and the western one is called the "shallow" aquifer. These two are the only aquifers which receive rainwater directly by seepage. Below them, there are artesian aquifers (aquifers with water under pressure, sealed off from the atmosphere by impermeable rock). Unless a desalination program is implemented, the artesian aquifers will have no utility for man, because they contain about one thousand parts by weight of chloride ions per million parts of water, four times the maximum chloride content of potable water.

[12] "Environmental Problems in South Florida," *op. cit.*, p. 8.

[13] Former Interior Secretary Udall, in a recent report, has suggested that if a new jetport is built in South Florida, revenues could be raised from taxes on its activities ("Beyond the Impasse: The Dade Jetport and the Environment of South Florida," Dec. 1969, obtainable from the Overview Corporation, New York). If such a jetport were to become as busy as the Dade County Port Authority predicts, handling 50 million passengers annually by 1980, one could tax the passengers a dollar apiece and buy the land in two years.

Suggestions for Further Reading

Bent, Arthur Cleveland, *Life Histories of North American Marsh Birds.* Dover Publications, 1963. Best source of information about the marsh birds inhabiting Everglades National Park and the Big Cypress Swamp.

Browder, Joe, "In Retrospect: The Everglades, the Jetport, and the Future." *Audubon Magazine*, March 1970. An excellent article, by the man who spearheaded the Audubon Society's efforts to stop the jetport, on the inadequacy of the decision at the federal level to relocate the jetport.

Egler, Frank E., "Southeast Saline Everglades Vegetation, Florida, and its Management," *Vegetatio*, Vol. III, p. 213, 1952. A technical but readable discussion of Everglades vegetation, with especially interesting sections on hammock formation and evolution.

Environmental Problems in South Florida. Report of the Environmental Study Group of the National Academy of Sciences and the National Academy of Engineering. Spotlights some of the harmful effects on the air and water in South Florida which will result from a jetport and from uncontrolled land development.

May, Julian, *Alligator Hole*, illustrated by Rod Ruth. Chicago, and New York: Follett, 1969. A delightful book for children on the wildlife in an alligator hole in the Everglades.

Robertson, William B., Jr., *Everglades—The Park Story*. Coral Gables, Florida: University of Miami Press, 1969. Best general source of information about the park flora and fauna. The photographs are excellent, as is the brief history of early Indian settlement in the Everglades.

Udall, Stewart, *Beyond the Impasse: The Dade Jetport and the South Florida Environment*, December 1969. Obtainable from the Overview Corporation, New York. A new kind of jetport for South Florida, one which might coexist with the park, is proposed in this provocative study.

United States Department of the Interior, *The Environmental Impact of the Big Cypress Swamp Jetport*, September 1969, obtainable from the Department of the Interior, Washington, D.C. A thorough analysis of the damaging consequences to the park of the proposed commercial and training jetports.