FGM 4
Interviewer Cynthia Barnett
Interviewee Howard T. Odum

12-13-01

B: I am with Dr. Howard T. Odum, a graduate research professor emeritus in the University of Florida's Department of Environmental Engineering Sciences on behalf of the Samuel Proctor Oral History Program at the University of Florida. Dr. Odum, who will turn seventy-seven in two weeks, is the longtime director of UF's Center for Environmental Policy and the founder of the University's Center for Wetlands. He is recognized worldwide as one of the pioneering figures in the development of systems ecology. He is known for emphasizing both the interrelatedness of humans and nature and balancing energy resources and for developing an economic model to help society quantify the value of its natural resources. In addition to nearly 200 scientific papers, he has published . . .

O: That's probably 300 to 400.

B: Okay, in addition to nearly 400 scientific papers, he has published 12 books. The latest, A Prosperous Way Down, written with his wife, Elisabeth C. Odum, was published this year.

The interviewer is Cynthia Barnett. The date is August 16, 2001. The interview is being conducted at Dr. Odum's home, 2106 Northwest 9th Ave in Gainesville, Florida. Dr. Odum, where were you born and in what year?

O: In Durham, North Carolina, in 1924.

B: Who were your parents?

O: My father, Howard W. Odum, a sociologist at the University of North Carolina, and mother, Anna Louise Kranz Odum, of German stock or descent, from Tennessee.

B: And what brought them to the Chapel Hill area? You father's job?

O: Yes, he was head of the Department of Sociology. Before that he had been what they now call provost at Emory University.

B: And what was it like growing up in Chapel Hill in the 1920s and 1930s?

O: You had three groups in school: the country people, very poor in the Depression time; and the millworkers, and the mills had closed and they were poor; and then there were the faculty kids, and they at least had all their needs met, and the school was a melting pot like the rest of the country and disturbed with the changes in progress.

B: Did the groups intermingle?

O: Some, not really much.

B: So you were with the faculty kids?

O: Yes.

B: Most of your growing up?

O: We were stimulated all the time by playing chess and hanging around the university or doing something in libraries.

B: Did your family know Frank Porter Graham (President, University of North Carolina, 1930-1949; U.S. Senator, 1949-1950)?

O: Yes, Pop and President Graham were close colleagues in the development of the university there.

B: What are your impressions of Frank Porter Graham? What are a few memories of him?

O: Genial, liberal president. I heard lots of conflicts between my father at home, but over trivial matters.

B: Can you talk about what it was like growing up the son of someone as renowned and prolific as Howard Washington Odum?

O: One was not so conscious of those things, and reputations were still being developed, so all the kids growing up had a vague notion that their parents were doing something useful. We spent a year, when I was going on five, at Rollins College, as he was a visiting professor, and so I became imprinted with Florida swamps and turtles and cypresses and bald eagles. I think that imprinting affected me; it brought me back to Florida years later.

B: What do you think drove your dad, looking back, to work through the problems he did, involving race, folk culture, and welfare in the South? What do you think was the driving reason . . .

O: And the regionalism that he is known for as well.

B: Yes.

O: Which is really, we would now call that a systems-view, although that word was not in use. He came out of a poor farm near Covington, Georgia, and delivered milk, and developed a folk feeling. His education was all classic Latin and Greek, and he was always quoting his parables out of those sources, and in some way he ended up with a broader view, and later went on to get both a Ph.D. in sociology and psychology in northern schools, Clark and Columbia.

B: How much of his work did he bring home?

O: His study was cluttered, even more than mine. And so his work was at home, and the discussions around the table probably influenced

the youngsters. But after the Second World War when I came back, then twenty one, I really had interactions with him for a year there before I went on to Yale.

B: So you lived at home during that year?

O: That's right.

B: And that was the time when you talked to him more about his career and his research?

O: That is right. And how he would approach things.

B: What impact do you think his scholarship had on you?

O: Well, at that time he was known over the country as the president of his sociological society and so on, but he had spent a year as visiting professor at Yale, which is how I came to go to Yale. But at that time he said that what was most important was making contributions to concepts and theory, which had not been his forte or what he was known for. He thought that this was the most enduring model, which became my lifetime guide. My major professor was a similar type who did not go to meetings to become a celebrity but stayed home and did the writing and the detailed work. These are patterns that are not so popular now.

B: Yes. And are you referring to G. Evelyn Hutchinson?

O: Yes, right.

B: Okay. It is remarkable that your brother, Eugene, is also a pioneer figure in the field of ecology. What do you think it was about your upbringing that drove you and Eugene both into careers in ecology?

O: Gene is eleven years older, and he was important in my early development because he would teach me things that he had just learned in school.

B: Eugene did?

O: Yes. So, even after he left and was at graduate school at Illinois, he would send back things for me to do, go out banding birds, and doing the things that he was interested in in those days, and that was ornithology and not really ecology. But I think my father's influence was encouraging us to write, and so Gene would put out a local newsletter for the neighborhood, and I was encouraged to write as well. And so I think those influences plus the general university matrix in which we were embedded, encouraged us. But Pop was always talking about that larger scale, I think, in effect it transmitted a systems-view to us. Later on, during my military service in meteorology, I learned to look from the large-scale down. You cannot predict the weather looking out the window; you have to look at the frontal systems and so forth.

B: Now, was your father's view of systems a human view and yours a natural view?

O: His, of course, was human, but it was tied to resources as well. See his books on regionalism and southern regions, mapping all the resources in the South, and how he tried to deal with the ridiculous situation where the South was importing everything when it had the resources. Of course, later it developed its economy after the Depression.

B: What are your earliest memories related to nature?

O: Well, those memories in Florida, as I say, living at Rollins College in...

B: And that was in Orlando?

O: Winter Park.

B: Winter Park, yes.

O: That lake is still there with the little train gone, and not so many turtles there, and it is pretty polluted. But the ivory-billed woodpecker and the Carolina parakeet were going extinct then, and we were much influenced by the Audubon Society writings on conservation.

B: But you were only how old at the time?

O: I was going on five then.

B: So you did not know about the ivory-billed woodpecker or the Carolina parakeet?

O: Oh yeah, pretty much. Again, my brother's influence on me. And then of course, later I read for myself.

B: Wow, so even before age five you were aware of these two creatures.

O: Yes, I was raised a naturalist.

B: Was that your mom and you dad . . . or all Eugene?

O: That was Eugene. He was, as I say, a bird person in those days.

B: How did your mother influence you?

O: Mothers probably determine your character in many ways on small scales, but she was very much . . . her mother, my grandmother, was a strong feminist, and father even had to leave town when she came to visit to avoid frictions because he had taken her away from her mother.

B: This was your grandmother? The feminist?

O: Yes.

B: What was her name?

O: Fannie Leber Kranz. Her husband had died. I think my mother was like many of the women who were highly educated in those days,

they did not have enough outlets for a career, so she was frustrated, and it contributed to her asthma and so on.

B: Was that your mother?

O: Yes, my mother. But she was, my mother was, a member of the American Association of University Women, and so on. But she also did things that women were expected to do, which was run a big house with fifteen rooms that Pop insisted on building as part of the complex that he had from being poor in the post-bellum South. We lived in a big house, the biggest in Chapel Hill in those days, on the highest hill, a giant stone castle. Later on, after our parents died, none of the kids wanted it. It was too big for us, and we sold it to the Christian church. It is a Christian church now.

B: So it is not, it was not there on Franklin Street? It was out . . .

O: It was out just south of the medical school.

B: So you sold it after he passed away.

O: Yes, after Mother died.

O: I recall the time it burned down when I was about twelve. It was a Sunday afternoon with February winds. You know, it was a small town of a couple of thousand people. The word got around, the Odum house is burning, and everybody in town came out, and they moved the furniture out and sat in it while the volunteer fire people tried to put it out. And they would get one side out and then it would catch on the other side. It was burned to the ground, but it was the biggest social event in chapel Hill.

B: Do you remember what year that happened.

O: I would have to look it up to get it exactly.

B: And did your dad rebuild it?

O: The insurance companies did rebuild it.

B: What caused the fire?

O: The redwood shingles and sparks coming out of the old-time furnace.

B: So the house was an overcompensation for your dad's upbringing?

O: Perhaps, yes, perhaps.

B: Who else besides your mom and dad and Eugene influenced you when you were growing up? Anyone we should mention?

O: I decided I would go into science from my seventh grade teacher, Mrs. Davis. As often . . .

B: Was that at Chapel Hill High School?

O: Yes, Chapel Hill High School. In those days I started with a class that had about twelve people in the first grade and graduated with forty. That was the entire class. So you get a lot of individual attention that way, and there were good teachers along the way.

B: How did you decide to pursue zoology, and how did you choose North Carolina State in Raleigh for your undergraduate work?

O: No, not in NC State. No, it was University of North Carolina in my home town, Chapel Hill.

B: Oh, so you went to undergraduate school at Carolina.

O: Sure, and I lived at home. To get some college influence, I joined a fraternity (Chi Psi), and learned how to at least be civil with people with whom I disagreed entirely on everything.

B: What sort of things did you disagree with people about?

O: Well, in those days, I was a teetotaler and I was raised that way. And their attitudes on women and race were pretty primitive and sophomoric, and of course, the world was coming apart with the

war, and so you had sophomores running fraternities, flunking out, and things like that.

B: Yes. How did you deal with this? These were your fraternity brothers . . . you were an undergraduate teetotaler.

O: I was still living at home, so you know, the usual thing, you would argue some of the time and just keep quiet some of the time. They called me Ichabod.

B: What led you to volunteer for the Air Force's meteorology program?

O: Well, all of us at age seventeen were trying to decide what would be a good branch to go into, and I saw this advertisement that they needed meteorologists. I was taking twenty-three hours and so on, trying to get enough math and physics to get into good programs, and I applied and was accepted, was sent to basic training in a funny place, Miami Beach of all places, which was great to come back to Florida. And then we went for engineering training, and they happened to send me right back to Chapel Hill, North Carolina, where they had a pre-meteorology school, and then to officer training at Chanute Field, Urbana, Illinois. As Second Lieutenant I went on from there to forecast weather at the Glider Base at Laurinberg Maxton Base in North Carolina. I had made high grades, so I was picked to go to tropical weather school and sent to Puerto Rico, and later on they set up their own tropical weather school in Howard Field, Panama Canal Zone. So I was there for a year as an instructor in tropical meteorology. This is extremely important to me because you learn not only about the earth and processes and engineering approaches to things, but also this view of the top-down, the systems-view, the real systems-view.

B: Was there a significance to the war effort in the meteorology program? Or were you sort of removed from that?

O: No, this is all focused, all this instruction had to do with the people we were instructing coming back from the Pacific and they would head back out. And we were trying to develop new methods of forecasting the hurricanes and so on. For example, they sent a civilian down to learn from us, named Robert Simpson. Later on, after he learned something, he went on to make the Saffir-Simpson scale that you hear about on the television, this was his scale of hurricane influence. As part of that training, I spent a month with the hurricane patrol out of West Palm Beach. And that was flying into hurricanes.

B: I did not realize they did that that early.

O: That was when it started, and it was operated through the Air Force at the time. It was later made civilian. We went through four different hurricanes during that period. In those days they did not use radar, but flew in at ground level in B-25 airplanes. We would be about six hundred feet off the water and trying to take what is called double-drift measurements of wind velocity. The torrential raindrops were slapping the plane, and it was in yaw turbulence sliding back and forth--very exciting. You just could not have a more interesting training than I was lucky enough to have in the Air Force.

B: Yes. So when you came out of the Air Force, you did not go straight to Yale?

O: No, I came back to finish an undergraduate degree in zoology because I had already been assisting Dr. R.E. Coker with his fish

collection before I left, when I was still in high school. Dr. Coker, who wrote The Great Wide Sea, helped set up the marine programs there at the University of North Carolina, which I later reinforced when I came back to that department. But in the meantime my father, at Yale visiting faculty, encouraged me to transfer and study with G. Evelyn Hutchinson--ecologist--geochemist. So I finished the undergraduate degree and went on to Yale. In those days I was going to find the secret of life. In the first year of graduate school at Yale, and reading one of the famous texts on the dynamics of biochemistry, I suddenly realize life is just a complex system, so if you are going to try to understand complex systems, this is not the best scale with its fantastic costs for just getting measurements at the microscopic level. Instead, let's go upscale and work with environment and humans where you can see what you are doing, and then work out the principles of complex systems which should apply to everything. So that has been my lifetime theme. And I think what the world needs to do, is to realize that there are these common principles of energy, materials and information that apply to everything. Humans, in the midst of it, think that they are making choices, and they are, but they are choosing between actions that fit the principles and thus will prevail, and actions that don't fit and fail. This concept is hard to get across, even to those in the ecological societies. We even have a controversy with a former student about whether deterministic principles that apply both above and below the human scale apply to ecological economics, which is a field which we started, relating people, environment, and money.

B: Are you speaking of the former student, Costanza?

O: Yes.

B: Let me go back for a moment to Yale, just so I can finish that idea. G. Evelyn Hutchinson. . . was this way of looking at systems that you began to undertake, was this different than how ecologists have looked at the world before?

O: Oh, yes.

B: How so? Could you explain that?

O: Ecology at that point was defined as a relationship of organisms and their environment. In other words, it is what is now called autecology, science of a small scale. One of Evelyn Hutchinson's fields, biogeochemistry, which is the cycles of materials, is a larger scale systems-view of the environment. He got into that because of his mineralogy father, and so on. So that reinforced my orientation from meteorology to start with a large scale and top-down view. And then we also had a lot of population ecology at Yale, which was started by Evelyn Hutchinson following Lotka, and in his mind there was no conflict there. Out of the students that came out of that program, some retained a large scale, and I am an example. Those who decided to emphasize population ecology went down to a smaller scale again, and that entire society has been hurt by it. People who study one scale call it a discipline, and they do not realize that every scale is driven by the next larger scale that uses parts from the lower scale. Science is hung up on the idea that basic is smaller. However the correct answer is that basic is both smaller and larger.

B: I still do not quite understand the controversy though, between the two ways of looking at population.

O: All right, the ecological community is our there . . . you see the forest, the trees, the birds, the microbes and everything. The smaller-scale view says this is the struggle of existence between competing populations, and that it is seething, and first one thing is ahead, and then something else is ahead, and when it is disturbed you get more variety, and that is all there is to it (an anarchy view).

B: So, Darwinism?

O: Well, early Darwinism, The Origin of Species. Darwin's last book, The Descent of Man, was important reinforcement for me. It is entirely a larger systems view. There is a natural selection for the systems that are organized to be cooperative, including the humans. That is the trouble for so many in the ecological societies who never read The Descent of Man.

B: So where does the value aspect come in? That is so important to you.

O: Okay. The systems concepts were developed during the Second World War including meteorology. In the post-war university there was much discussion of systems information and energy and a very remarkable book published earlier, Physical Biology, by Alfred Lotka--Hutchinson put me onto it. The principles of thermodynamics include three laws, and Lotka proposed a fourth one. I realized as a graduate student then, that this was the explanation of nearly everything. It was called the maximum power principle. The self-organizing processes that you have in the forest or in a chemical solution or in the stars or in human affairs, the

systems that prevail are those that, as first priority, pull in the most available energy resources, and as second priority, use them efficiently to make all the processes perform at the maximum. And people say, well why? Why should that be? Well, it is natural selection, but not just on an organismal level. I mean, in addition to selecting organisms, natural selection chooses system design, including all the components of a system, whether it be people interacting or birds and trees interacting. There are all kinds of connections that could be made, and the ones that reinforce are selected. For example, when the bees pollinate the flowers, that reinforces both the bees and the flowers. It is a closed loop reinforcement, and therefore that design takes over. I do not understand why so much of science, and particularly ecological people, have trouble with understanding the maximum power principle. And we have changed it and refined it, and we now call it the maximum empower principle.

B: Does man not have an advantage, an unfair advantage, in this system that you just described?

O: Humans are suffered on this earth as long as they feed back and reinforce their environment. That is the message that is gradually getting out. So what do the humans do for the environment, for the whole world, that was not there before? Well, they are information processors, both as individuals and also in their social mechanisms that their culture developed, so that they collectively can have this fantastic information development. That is why people are reinforcing the earth. Of course, information civilization has a

temporary pulse from using fossil fuels, but on a longer scale, the pulse is part of a repeating pattern.

There are a bunch of corollaries that we have learned about all systems that are part of the energy hierarchy concept. Systems store energies and then use them in a pulse, and that gives more performance. An earthquake gets more done than if the plates of the earth moved gradually all the time. They would not get as much done as by building up a strain and then releasing it with a sudden surge. We find pulsing in the molecules, the cells of organisms, in ladies with pregnancies, and human sleep; pulsing is the normal pattern to plan for. The world is using the sustainable steady state model where growth builds up and levels off. And that came out of ecology earlier, and that is Cowles' model. It is not correct. Systems build up and have a consumption pulse, and then they reset and do it again. I think most ecologists now are coming to realize that. Other colleagues contributed to that consensus such as C.S Holling.

B: When are you developing these theories? Is it after you had left Yale?

O: I started as a graduate student with my dissertation, The Biogeochemistry of Strontium.

B: And I know before you arrived here for good in 1970 you were at UF, Duke, University of Texas at Austin, University of Puerto Rico, and full professor at UNC Chapel Hill. What were some of the most important times during that time when you were a young professor? What sorts of theories were you developing during those years?

O: I came first to Florida in 1950 for four years, and at first I was doing biogeochemistry, and I remember one senior professor who said, "when you gonna do some biology?" W.C. Allee had come to Florida as Biology chairman and encouraged me to do the Silver Springs project with which we developed energy systems theory. W.C. Allee, who was a social-ecologist, had published this great "AEPPS" book, named after five authors, Allee, Emerson, Park, Park and Schmidt, which had summarized fragmented knowledge of ecology, that encouraged my brother to do his textbook Fundamentals of Ecology. But Gene had an out-of-date framework and asked me to collaborate authoring two chapters on energy and population. I just brought the new stuff out of Yale, and helped him organize. Gene forgot his original offer to include "with collaboration of" and left my name off the first edition.

B: Your brother did?

O: And so I told him I would get a lawyer if he did not correct it, so the next edition, he put it in.

B: My gosh.

O: There are complex exchanges between brothers. There has always been a need for us to hold together as best we can, make joint contributions, and reinforce by sometimes writing together, but there have been problems.

B: So you have also been competitive?

O: Well, I never felt it, but my brother did. It is described in Gene's new biography authored by Jean Craige, a nice lady in Athens (Director, Humanities Center, University of Georgia). I was eleven years younger and didn't expect to be equal until later.

B: Well, you were the upstart little brother.

O: Besides, my background is entirely different, starting with Air Force meteorology. Returning to college, I took the equivalent of an undergraduate major in chemistry along with zoology. My wartime engineering training was all quantitative, and his was in another direction. But over the years, he has been a genius at reaching people. During the war, he taught eighteen hours of elementary courses to ignorant kids off of Georgia's farms and learned to reach people who have poor backgrounds. And so that has been his strength, to cultivate ways of feeding ideas to people at a rate they could take them, and not shocking them. Whereas my tendency is to say what is correct, even putting down stupid ideas. And, of course, that is not the way to influence people.

B: So when you read his biography recently, you learned things that you had realized?

O: I scanned it.

B: That is interesting. An yet over the years, you have collaborated on books.

O: Sure. For example, after Gene's son died prematurely (liver disease), his mother, Martha, asked us to write a co-authored paper. I wrote the draft of a paper authored by William Odum, Gene Odum, and myself on the pulsing paradigm, relating theory and Bill Odum's work on marshes. The pulsing idea was already in my 1983 book Systems Ecology (last chapter). The paper was a good chance to use my nephew's very nice estuarine research, and Gene's acceptance among ecologists, to advance a principle. So we would do things like that. We put out a paper recently. I think lots of people in

ecology are like a Romanian ecologist who approached me at an international conference a couple of years ago in Denmark. He said, "I hear your brother is the good ecologist and you are the bad ecologist." But he says, "why do you not come give us a lecture and let us see."

B: Well let me ask you, what does he mean by you are the bad ecologist and your brother is the good ecologist?

O: Well because . . .

B: Because you challenged the system?

O: Challenged sometimes. I am primarily an environmental scientist on a larger scale. The consequences of each scale of science are driven by those at the next larger scale. People at one scale do not want to be told that the answers are not in modeling up from their parts, but in aggregating all this detail in order to deal with the next scale. On any scale, half the knowledge is about the parts and the other half is in emergent combinations. Science is badly hurt by letting disciplines study only one scale.

Also, if you are in an engineering college, ecologists assume that you are somehow hurting the environment.

B: I see, you are messing with it. You are manipulating it somehow.

O: Something, who knows?

B: Would you say you are close to your brother?

O: We were very close, up until the time I had the problem with the book, and then . . .

B: And that was early in your careers?

O: That was in 1953. But we have worked together many times since, but I had to learn to be cautious. We were given the Institut de la

Vie prize in 1975, and that was great, going to Paris. That is a group that normally does not look at environment, but with new world interest in environment, they departed from the molecular biology interests and gave us the prize.

B: So you were awarded that prize jointly?

O: Yes. Some of the people on the awards committee were from India, so Gene sent me a letter and said, let us put our summary papers of our presentations in the Indian journal, Tropical Ecology. Mine introduced the concept that we now call transformity, a fundamental new concept. So I did, and it came out in 1976. But his turned up instead in the front pages of Science, and he got the Tyler award the next year. On the other hand, Gene pushes our stuff. People say that when Gene is ready to adopt one of H.T.'s ideas publicly, it must be all right.

B: That must be frustrating.

O: It is not, because I have a different model for my life's role, one advocated by my father in his later years. What's important is to contribute new synthesis. Breaking new ground is the model I have. My major professor at Yale, Evelyn Hutchinson, was that way, not trying to be influential. He wrote his papers and books, and once in a while he would go to a meeting, and inspired students by example. However, there's more than one useful model for scientists to follow.

B: I know you had grant work in Florida as early as 1953. Could you talk about some of the earliest work you did in Florida?

O: Florida, in those days, did not have research grants, it was just starting. The Office of Naval Research gave us one of the first grants

in the entire university, comparing springs and their ecosystems. And then we had a little project on phosphorus in waters from the Florida Geological Survey, you know, $500. And there was one from engineering on red tide, and one on boron. So understanding of chemistry of ecosystems developed using biogeochemistry, the concept I had learned from Evelyn Hutchinson, a limnologist. (Limnology is the study of streams and lakes.) And when W.C. Allee came down from Chicago and set up changes in the department of biology, he gave me the limnology course. My early limnological work showed the role of phosphorus, which seemed to be extreme in Florida, appearing in waters in all kinds of interesting places. Our early work showed where things were eutrophic, that is nutrient-rich, where they were oligotrophic, and the ecological consequences. We did not have a lot of measurements on $500, but even now these are the only ones they have to decide how Lake Okeechobee and other places have changed.

B: So those early studies are what they rely on now to measure?

O: Well, you cannot rely on two or three numbers very much, but still this survey suggested principles.

B: What did you learn about the role of phosphorus in Florida's lakes?

O: Wherever the acid waters of swamps cross phosphate rocks, then you had more phosphorus, and so you had more fertility.

B: Was that good or bad?

O: Well, in those days, that was regarded as good. And Canada had sent people to work with Hutchinson to talk about fertilizing all the lakes of Canada. So the idea in those days was to make everything more eutrophic. But in Florida, it was already eutrophic in a great many

places and surviving fairly well with it. I mean ecosystems were fairly well adapted. Many of the fish could live with eutrophy and the low-oxygen conditions, and so on. The chemical tests made blue solutions. One day, all of a sudden, this blue-black solution resulted in tests of the tributary of the present Rodman Dam. My god, we have discovered a new phosphate deposit. Of course, it turned out to be Orlando sewage. Phelps had made his name well-known in environmental engineering for understanding the behavior of oxygen in water. Retired, he came down to the University of Florida and was helping out with waste studies in what is now the Center for Wetlands. I came and showed him some of the results. I was fresh out of school, a couple of years out, and he was my present age. And he says, oh well, nutrients are not very important. It was just incredible the misunderstanding in those days of the role of nutrients in controlling all of the waters and their ecology in Florida.

B: And what was Phelps's first name? This is the guy the Phelps lab is named for?

O: That is right.

B: Okay, I will fill that in. So, if you could just follow up on what has changed about the phosphorus in our lakes now.

O: Well, whenever consumption is greater than plant production, then the consumption process turns loose nutrients; it turns loose the phosphorus and the nitrogen and other trace materials needed. Modern society, because it burns fossil fuels and uses fertilizers straight from mining, turns loose huge quantities. Now we have this supereutrophy wherever humans are: it comes off the highways, out of the cities, off the sewages, out of the boats, off everything. So all

of a sudden we have more nutrients being turned loose all over Florida than it can accept. Of course, one of our greatest contributions was showing how to use wetlands to regulate nutrients, and the University of Florida probably did not get enough credit for it. This was done after I came back to Florida in 1970, and we set up the Center for Wetlands with a $1,000,000 grant from the Rockefeller Foundation and NSF (National Science Foundation). I knew wetlands would work from studying nutrients in salt marshes in North Carolina and rainforest in Puerto Rico.

B: And the Amazon?

O: Our work had included measurements in soils there. Wetlands are nature's way of taking in excesses and binding them back into organic matter. They redeposit nutrients in peats, and we set up experiments to show that for Florida. We held a national workshop in Gainesville in 1972-1973. And immediately everybody who came to that national workshop went home and wrote proposals to treat wastes with wetlands.

B: So even scientists did not know the value of wetlands before that time.

O: They knew in general that they were interesting ecological places, but not this particular role of wetlands in world purification. Many scientists even now, the negative-type conservationists, will oppose the use of wetlands for this purpose. However, you do not have to use natural wilderness wetlands for this. You can build new ones, and that is what we learned to do. It is easy to control water levels, and once you get the right hydroperiod and multiple-seed it with many kinds of species, nature self-organizes and gives you back a

pattern that fits that particular condition. So this is now done all over the world, and with magazines and journals recording successes. This was one of the successes of a new field, Ecological Engineering. My former students founded the Ecological Engineering journal, and we now have a new society, and it met for the first time in Athens, Georgia, this year. We had my brother, Gene, give one of the keynote speeches.

B: What was the name of the new society?

O: American Society of Ecological Engineering

[End of side 1, Tape A]

B: This is side two of tape one, and you left off talking about the American Society of Ecological Engineering.

O: Ecological engineering differs from environmental engineering in that it expands the scale to include the ecosystems around the engineering technology. For example, consider wastewaters coming out of a pipe. Environmental engineering works with processes in the technology to try to get the waters to be appropriate to the environment. But ecological engineering takes it a step further and says we are going to let self-organization, that is nature's design, work with us. And so we are going to adjust not only what we put out, but help the environment manage it in such a way that it develops an interface that benefits from the waste, because there is no such thing as waste in ecological engineering. It is potentially useful byproducts, but not waste.

B: That is interesting. And what year again was the national wetlands conference?

O: Well, that was 1973 I guess. Ed Pyatt was chairman of our department and helped us start with a one year Rockefeller planning grant, which included that workshop. And then from that we turned in a $1,000,000 proposal, and we got a lot of endorsements. We had Reuben Askew's (Florida governor 1971-1979) letter endorsing it.

B: How about Stephen C. O'Connell (President, University of Florida, 1967-1973)? Was he instrumental?

O: He approved it. I thought maybe he might not approve it because I had testified in favor of a wildlife professor who had been an environmental activist in IFAS (Institute of Food and Agricultural Sciences), attacking agricultural concepts. They wanted to fire him, and there was a hearing. Manning Dauer (University of Florida Distinguished Service Professor, Department of Political Science, 1933-1987) was the attorney for defense, and he had me testify. But my testimony was just to show that IFAS at that time was not following as free policy for faculty as in engineering and biology. I had been in both of those departments, so I could speak with some authority.

B: What was the name of the wildlife professor?

O: That is one I am going to have to look up.

B: Okay, we will fill that in. And . . .

O: He eventually left. I think he chose to leave, but it stirred up the campus badly.

B: What specifically was the controversy? Why did they want to get rid of him?

O: I would have to review that.

B: Okay, we will fill that in. That sounds like an interesting story.

O: It is. It was a time of university activism regarding Viet Nam, race, and environment. The public perception was that O'Connell, a jurist, was inaugurated to quell activism. I believe the first Earth Day was 1967. I was still at the University of North Carolina at that time. So in Florida in a time of expanding environmental activism, they were trying to punish a person because he was speaking out . . . but I had looked at his scientific papers, which seemed to be reasonable science, and there was just no basis for firing him.

B: That brings me back to when you first came here as a full professor in 1970. I want to ask you to characterize the environmental outlook of the three campus groups: students, faculty, and administrators.

O: Here?

B: Here in Gainesville, yes. Was the student body beginning to pick up on the environmental movement that we were seeing?

O: Yes, it had not been as active here as it had been in some other universities, such as Chapel Hill. But nonetheless, it was developing, but later. At Chapel Hill, I had been a part of three departments. I was joint professor in departments of Botany, Zoology, and Environmental Science and Engineering. And I also organized the Marine Science major curriculum program, an interdepartmental major, in memory of R.E. Coker, my early teacher. We also set up the ecological degree program. I learned from being

interdepartmental that no one chairman would back you. So when I came to Florida, when they asked me if I wanted to be jointly appointed in other departments that I had once been a part of, like biology, I said no. If I am going to do engineering, I am going to stick with it. At that time, this Department of Environmental Engineering Sciences was really quite innovative because it had half engineers and half scientists, and they were all trying to deal with these environmental problems. So it was a very creative time, a lot of mixing, hydrology, ecology, and then our innovation with wetlands. To answer your question, I think all the environmentally-related departments were innovating at that time.

B: You helped shape the university's policies on environmental education during that time? How did the administration . . .

O: As to the question of what the environmental curriculum should be, there was already competition as to who was going to do environment. Possibly because of my proposals, I was made chairman of a university-wide committee on an environmental science undergraduate degree. Bob Bryan was provost then, and later acting president.

B: Robert Bryan (Acting president, University of Florida 1989-1990).

O: Yes. They appointed administrators to my committee, so we met for a whole year and put out a report. Archie Carr was on it. The question was whether to put in an undergraduate environmental science program, and it split down the middle. The member from the medical school abstained, and forced the vote into a tie, which meant that there was no degree recommended. . . So we submitted a

final report that had a weak majority conclusion and a strong minority statement for a degree.

B: Did the vote line up with all of the administration opposed?

O: Yes, because they wanted to push their own programs, they did not want one campus-wide program. So the IFAS dean was against it, and my chairman was against it, and so on.

B: And what was the medical program's beef with it?

O: He said environment is "fly-by-night." He thought it was a passing fad and did not see any point in setting up a new curriculum.

B: And now they have a whole College of Natural Resources.

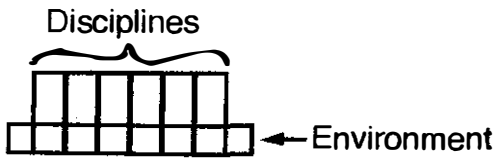
O: Well, that is later when it came up again, 15 years later. But at that time, I went out of town for a month in the summer. When I came back, one of the deans had come over and picked up all the copies of the report and destroyed them. I let it pass; there are times to fight, and times not to fight. Then years later, the pendulum on the environment swung back. We had a lot of strength on this campus in environment in maybe twenty departments. I mean, there was entomology, and aquatic plants, agricultural engineering, and all kinds of places. I proposed an environmental college and hit a nerve, and all of a sudden it caught fire. They set up a set of committees, and the first time they had the faculty interested to come out to a general meeting, 300 turned up. Later on, it sifted down to smaller numbers; the outcome of that is the program that Stephen Humphrey now directs (College of Natural Resources and Environment). Even then there was the struggle as to whether that should be within IFAS or be separate. But of course, it is a virtual

college, and it does not have any budget except for some fellowships and some secretarial help.

B: Did you argue that it should be outside IFAS?

O: Yes, I thought it needed to be independent, a full fledged college. That is still the issue now. So much for the undergraduate program.

For graduate studies, in order to give strength to ecology, I proposed an "ecology independent major," and that was picked up. It was separate at first, but then it was combined into this environmental college. Humphrey picked up on this graduate major, but it is not as good as a regular college. The problem is that the environment cuts knowledge across old disciplines. With the typical disciplines, chemistry, physics, and forestry, etc., you can line them up in parallel (here I referred to a drawing on paper),



like that, each one with its scale and a set of principles. When you go to train somebody in the environment, you need some of each of the old disciplines. The whole country now is starting stronger environmental programs. For example, I check at Yale every summer when I go up there, and they just put in a new environmental program they adapted from their former forestry department, renamed it, and are moving it towards an environmental college. Some places have environmental studies, which are pretty weak in that they are not required to learn

quantitative science. They learn the qualitative sides of it as part of good general education. Some places have hard-core sciences, and then others try to compromise between these ideals.

B: I guess we will go back to 1971 when Environment, Power, and Society is published. Could you talk a little bit about that book and its impact? That was one of your most important books, right?

O: Yes. We started writing chapters even as I was doing the rainforest work, and they were rejected at first. Then publisher Wiley changed their mind and encouraged me to finish it. This was an attempt to use systems concepts to understand all systems, but particularly this scale of humans and the environment. By this time we had evolved a set of symbols that represent the way the world breaks systems into units. It is a general-systems language, and it had an energy aspect and a mathematical aspect. It connects science to the verbal thinking that people have, everybody, including the mathematicians--as they were raised at their mother's knee. (I drew an example of a symbol of a water tank.) Well, my symbol language translates verbal models and immediately elicits what the symbols in the drawings look like. The minute you have done that, you have automatically written the equations for a computer program, so you can simulate the system. I guess that general connectivity concept hit a nerve. It was fairly new and many people were influenced. For example, the input-output energy people apparently got their ideas out of one of my diagrams in that book.

B: Is this the time when you explain the concept of emergy?

O: In those days we were still calling it embodied energy. It is energy that went into something, it is embodied. There were other

concepts with that same name that were getting confused, and people were attacking each other. In 1983, we realized that what we were doing is not what some other people were doing, and that it is separate, and it should have a name, not some English name that everybody would be confused about, which is what ecologists have done in the past. They keep taking English names and reusing them in some narrow way. We used a new word, emergy, which is short for energy memory. It is the memory of what was used up to make something.

B: And it is basically a measurement of the value of natural systems.

O: All real value, real wealth, if you like, requires work to be done. According to the second law of thermodynamics, everything diffuses apart, falls apart. You have to keep building it back up. You build your house up, and it eventually erodes and falls apart. Your body is doing that all the time. The work required to make something, or to sustain something, that work is real wealth, and that is the measure of it, and it applies to all scales. The problem is that available energy at one scale is different from available energy at another scale That is, it takes a lot of phytoplankton to make a little zooplankton to make a few fishes to make one giant fish. So a joule or a calorie of one level is not equivalent to that of another. (Here I referred to a drawing of an energy chain.) It takes a million calories at a lower level to make one at higher level. People who are trying to do energy analysis and deal with value have been using energy to measure work. They renamed available energy, by the way. They now call it exergy, which is available energy that can do work. But they are adding different kinds together as if they were the same,

and that is wrong. Engineers have known for a long time that they should not add electricity and coal because it takes four coals to make one unit of electricity. That principle applies to everything, so what we do is put everything in units of one kind. That is called emergy; it is a memory of what it takes through all the pathways in terms of one kind of energy. Each joule of whale required 10 billion joules of sunlight, to put them on an appropriate basis. The conversion from one to another is called transformity. Use of this value system is gradually spreading internationally. We had a conference two years ago here on emergy, and Mark Brown edited our proceedings book. We are having one September 20, the next one. Every other year we have this.

B: Could you give me an example of an emergy analysis you would do using a Florida example? Could you give an example that would help readers of this document see how this is effective?

O: One example to mention is from the book that has details: . . .

B: Environmental Accounting: Emergy and Environmental Decision Making (Wiley, 1996).

O: Yes. One of the example in there is the Santa Fe Swamp, which is the headwaters of the Santa Fe River, and also a part of the Santa Fe Lake. To save money, Georgia-Pacific was going to dig up that peat, about three meters of it, and use it for fuel. Of course, that takes away the natural functions; they did not realize how much. But the public had an instinct about it and opposed it. Georgia-Pacific proposed to give it to the county. The question is: how much is it worth, for taxes and other things like that? We had a radiocarbon measurement done. The bottom peat was 1,500 years

old. If you take the work of nature times 1,500 years, and convert emergy to emdollars, the economic equivalent, you have the value of the peat. It comes out to be 1.2 billion emdollars. Emdollars are the emergy share of the gross economic product. We think all public decisions need to be made with emdollars.

B: What was the reaction of Georgia-Pacific and public officials to your value?

O: That was really interesting. They sent lawyers around to visit. I did learn that they sent the same questions to my brother. I never heard the final outcome. But ours is published. The point is that environmental products are worth much more than you pay for them, because the money does not go to the environment. Money only goes to people to process products, and it does not recognize at all how much nature has put into it. Nature might have put a little in it, or might have put a lot in it. You cannot tell from just what you pay somebody to bring it to you.

B: You have said one problem with emergy evaluation has been fear of the correct answer by government and private sources. Can you explain?

O: When the mitigation business in Florida started, saying you can develop one wetland by enriching or protecting another one, the people getting ready to deal with this and their billion-dollar land values had me come around and present these concepts as a scientific method. Then they backed off because the state did not use it. The state wanted to use its present method, which is usually some kind of committee action. I asked one of the people, a former student, actually, in the Florida Department of Natural Resources,

why they were not using it, and why they backed off. She said they were afraid of it; they were getting a lot of money to protect the environment with the present method of mitigation, and they were afraid they might not get as much. Then the people whose private lands, the developers, who were trying to do the development, were fearful of something new. They believed they could do better with the present system of personal interactions and the present economic values. The idea among the public and most people is that value is market value, it is economic value, what people are willing to pay. They don't believe in a natural-value system. People in thermodynamics know there is, but they are arguing about the best way to measure it. The majority, particularly in a society that had two centuries of explosive growth, see no limits. They don't believe energy is relevant. If you want something, you just advertise, and you can just have it. That is the struggle between the reality of value and the public's perception. It is going to be a drastic change when the public realizes limits. I do not know whether or not I will live to see it, but our recipe for that is, as you know, in this new book, The Prosperous Way Down, which explains how to deal with it once the shock hits us.

B: Let me ask you, are we not doing constructed wetlands now? And private wetlands mitigation now? And do you think that is working?

O: Developing wetlands for wastewater is, I think, doing real well. But they keep doing stupid things like spending $100,000 to plant what they want to grow. By next year these are all dead and something else has come in and covered the area nicely, by nature. They have not quite learned the difference between brute force and self

organization, which is ecological engineering, which is to let nature tell you what fits. But there are plenty of problems like that, but in general there should be a wetland between every outflow of every agriculture and every run-off and every sewage drain and any open waters. I think that principle is out there. I am not up-to-date on how many of those mitigation swamps are really working. I think the notion that we will get rid of all the little ones and have one big swamp saved somewhere else is a mistake. The little wetlands are what keep the superficial groundwaters wet. Transpiration keeps the forest from getting too hot and exploding in fires when you get droughts.

B: So even one of the teeny-tiny wetlands you see when you are driving on the interstate, like those in the middle of the median, those are even important.

O: Absolutely. The big mistake in the forestry industry was to drain those, but they are not completely drained, so most plant and flora still have about five to ten percent of the areas in little cypress, gum or some other little wetlands. But they are partly drained, and the sooner they fill the ditches back, the sooner they will protect their own forest by maintaining the superficial water levels. In other words, nature's self-organization of water was to maximize productivity of the landscape, and that is what people want--the same thing. It was shortsighted to try to get that little bit of extra land.

B: We just took a short break, and you were just mentioning that emergy has been used in two lawsuit that were settled out of court. Are you able to talk about those at all?

O: Well, sure. In one, a landowner had dredged some mangroves down in Lee County, against the rules of both the state and the Corps of Engineers. The state lawyers heard about our method. It was interesting that they caught on to emergy quicker than my own students.

B: What year was that? Was it in the 1980s or 1990s?

O: No, it was in the 1990s, but it was not with the present administration of DEP (Department of Environmental Protection). When we had preliminary hearings, their environmental consultant resigned; then they had the second hearing and settled out of court. The market value of wood and a few fish was at the $1000 level, whereas the destruction of a whole coastal protection system of mangroves and tidal exchanges comes out with emergy evaluation at the $1,000,000 level.

B: Do you think eventually this will begin being used in development lawsuits?

O: I think so. It may take people a while to accept that the market value is not the appropriate public value. Market value is one correct value, it is what it is worth to people, it is what it is worth to businesses, but it is not a measure of the effect on the economy, the public economy.

B: So emergy will always be far greater than market value?

O: Usually, not all the time. Once, drought in Texas got so bad in one place that people were willing to pay more than what nature's water was worth. So it can happen, but not usually.

B: I know when you came up with the concept of emergy, you said you believed that having such a rational science-based measure of real

wealth would eliminate much of the rancor and adversarial decision-making that plagues environmental issues, but it seems today that the rancor is only growing greater, it seems worse than ever. Why would you say this is?

O: Well, that is part of any system, you build up and store the need for something, and when it gets to a threshold, then it flips. We already discussed that with earthquakes and with storms, and this also applies to human affairs.

B: So that is a natural occurrence, and you believe that will flip?

O: Sure. The best example connects with my father again. All during the time I was growing up, my father was always speaking for racial harmony, and he was one of the moderate southerners who were trying to say that the way to do it was to do it gradually. By doing it a little here and a little at a time, it looked to me like we were not getting anywhere, and nothing was happening. But of course, what you had was a gradual build-up of beliefs and so on. Then Martin Luther King hit the nerves, and it flipped. That is a good example.

B: So your dad was right?

O: Not quite, he was wrong about how to do it. Of course he was right about what he was trying to get done, but you can't make large changes gradually. He was partly right, you do it by educating and writing and so on, but it still does not happen until there is a controversy that brings the issue to the center stage so that everyone can look at it and flip.

B: I misunderstood. So there has to be some sort of boiling point?

O: Yes, there has to be some kind of trigger to release accumulated feelings in a pulse, which gets it done quickly. Human culture has

been built, in both genetic and social inheritance aspects, to do that, because that is what energy principles require of any system. The general-systems concept applies to human affairs in the same way. Pulsing maximizes performance.

B: Do you think both sides of these rancorous environmental issues will eventually have that same sort of revelation?

O: There are so many issues here, but the one we were talking about was whether a majority of the public would then be ready to accept a new valuation method for public benefit. Whether they will call it emergy or call it something else, it will happen in a flip, I think.

B: Is now a good time to talk about the controversy with the former student Bob Costanza? Was that about emergy? Or was that something else?

O: Bob was one of our energy systems graduates. He and Mark Brown were in the same class. He was in architecture when Harry Merritt dropped him, and I admitted him to our program, supported on our Department of Energy grant, which had been running several years. When we started emergy evaluations we were moved from the environmental division to the economics division. The new people managing that grant said "your stuff does not seem to be the same as the stuff out of Illinois, which evaluated embodied energy by the input-output method. We think you all ought to get together." So I sent Bob Costanza to Urbana. This worked pretty well. He got them interested in our method, but also adopted their method and came back with it About that time I went to New Zealand on a special fellowship. He finished up about the time I got back. In his first jobs, he applied our methods, but he was not having much

influence. He started interacting with Herman Daly at Louisiana. He believed he could get more influence by not opposing economists, but joining them. So he helped start the Society and Journal of Ecological Economics. He put all of us on the board of the new journal and got started. There were important conferences in Sweden and at the World Bank. At some point, however, there was a deep struggle there, and one of the main issues was input-output embodied energy versus emergy. Another was market value versus other values. So he took us off the board. Now they are using economic methods more. When my students had the 65th birthday celebration for me in Chapel Hill, North Carolina, later published as the book Maximum Power (ed. by Charles Hall), there was controversy over emergy. Most of my former students did not know what to make of it.

B: Is there a continuing conflict today between ecological economics and emergy?

O: No. We founded ecological economics, not only through Bob Costanza, but through other people and journals. Emergy is part of ecological economics. But that particular journal, since he has edited it, has not accepted emergy papers. The only time they published emergy was Mark Brown's paper co-authored with Bob Herendeen. So they published it because they thought it was a criticism, but the next year the paper was given an award as the best thing in that journal. But there has only been one in that journal. We publish elsewhere.

B: Is Costanza still the editor of Ecological Economics?

O: Yes, but he is no longer directing that society. I have talked to him since. I think we are both trying to do the same thing, trying to get economics and environment together. I think the ultimate outlet for emergy is for it to be adopted by the economists because they are concerned with people and value, whereas many ecologists regard that as a dirty application and are not interested. Emergy is opposed by three kinds of people: One is ecologists who regard this as some kind of application, if useful at all, as something applied, not basic. Then it has been opposed by some economists, who at first glance think that we are trying to displace market value, which we are not. Market value still applies for individuals and businesses, and that is what people have to use. Emergy and emdollars are not to be a substitute for market value. Then the third group includes some of the thermodynamicists who do not want to give up the idea that energies of different kinds can be added as measures of work.

B: I didn't understand the third group, I'm sorry. What was the third group?

O: Thermodynamicists, who do exergy analysis. Emergy analysis requires one step beyond their exergy analysis to convert exergy to emergy of one kind. My own background is pretty heavy with thermodynamics from both physical chemistry and from meteorology. In a paper I just reviewed yesterday for a journal, they were adding the joules of beef to the joules of corn as a measure of total production. And that is absurd because it takes many joules of corn to make one joule of beef, so to add them as if they were comparable is incorrect. Getting that across is slow because it is a paradigm shift, and people do not want paradigm shifts because all

of a sudden they would have to turn around and say, oh my gosh, every paper I have published should have been different. A new generation may be more open minded.

B: So the basic difference between you and the economists is that they put human value, and you place a systems value?

O: No, I do not like you to put it that way. The measure that we have that economists, I think, are going to use increasingly, is a second value, the contribution of real wealth, how to measure real wealth. Economists need to deal with that as well as market value, which is what people value. Both these systems, the circulation of money using market value, and the real wealth, are coupled together, and we know how. So emergy evaluation is not against economists, although we lost opportunities in the early years when some of our advocates came on the way you just did. When I came back to Florida in 1970 with some of these ideas, I gave talks in economics that were reasonably well-received. And then Engineering formed an Energy Center, and got a personable fellow, a former fisherman, named Tom Robertson, in engineering, under Dean Smuts, to coordinate the Energy Center. There was an energy crisis developing due to an OPEC embargo. Then he went around saying the economists are all wrong and Odum is right, and we have had to live that down. Tom Robertson, by the way, is good friend. Right now he is in Washington D.C. helping to manage an energy discussion group on the internet with about 500 members. I receive about 50 e-mails a day on the new energy crisis. This is part of a group that is called Die-Off, by Jay Hanson.

B: Oh boy, I have seen this. That guy found me. I know exactly who you are talking about.

O: Tom Robertson.

B: Yes.

O: The university-wide Energy Center of the 1970s did not pull the campus together, the crisis faded, and so they canceled it. Later, Engineering formed another one under Barney Capehart, which was narrow, only within engineering. And now, with Capehart retiring, there is no energy center except the solar energy center. So our Center for Environmental Policy is the main effort in publishing research to prepare for the new energy and environment crisis. We are just right now only a publication operation, with a secretary and some cooperative faculty, doing conferences and publications. We need to reestablish an intercollege energy center, but this university, with all its reorganization of trustees and all that, is in such a fluid state, I do not know where that initiative is going to come from. My attempt to talk to the new president scared him; he heard the word environment and ran.

B: Oh really? How about the provost? He seems to be environmentally conscientious.

O: He is different.

B: Let me ask you again about applying value. Pollution credits and things like industry solutions like wetlands-mitigation banks, how do those fit into your model? Do you see those types of things as effective?

O: Yes, the correct alternative is the one that fits the maximum empower principle. And we say empower rather than power

because then that means that we are adding energies on a common basis. The public policy that will succeed is the one that generates the most real wealth, which you calculate from emergy. The question with mitigation alternatives is: how much of this is equivalent to that? You need to compare on an emergy basis, which we immediately convert to emdollars, so that people can understand the magnitude.

B: Do you think that the people who are carrying out pollution credits and the like are doing it right?

O: Well, they are not using this measure now, so it is a guessing business. The EPA (Environmental Protection Agency) is now finally considering emergy. There is a former student, Dan Campbell, who is part of the EPA in Rhode Island, and some of its staff have been looking into emergy in this past month using a project in West Virginia.

B: Okay, so the concepts are the right way of thinking about it.

O: And the measures, the measures are sound.

B: I want to go back to 1971, because we skipped over something I wanted to ask you about. I think it would have been 1971 when Governor Reuben Askew made his first calls for Florida to manage growth. And our initial growth management laws passed the following year. Were you involved in the governor's first growth conference?

O: Yes. He had me on his speakers platform on one occasion. But then at a later time, he kept his distance.

B: Why? What happened?

O: It is hard to say. People get labeled as extremists or too abstract, and politicians try to be middle-of-the-road. On the other hand, he wrote us a letter.

B: For the Center for Wetlands, for your Rockefeller-NSF grant.

O: Yes, that is right.

B: What was it about your involvement in the growth conference that turned him off?

O: People who try to explain how society will have to adapt to no-growth sometimes get an image as opposing growth. But let me mention another occasion. Governor Bob Graham (Florida governor, 1979-1987; U.S. Senator, 1987-present), our present senator, had a later growth conference, and I was on that one. They had a lot of subgroups, and I was made chairman of one of the subgroups, with citizens of all walks of life. So we kicked around all these things, and then they had the big session with several hundred people in a giant room, and we all made reports. I made a report on our group, on what we had agreed on, and what we did not agree on. I said a couple of things having to do with valuation and also about the need to be working on what to do when growth stops due to energy shortages. Resource people agree that fuels are going to tighten up, although at that time prices were down. But he admonished me, saying growth will not stop.

B: Did he?

O: He said it was ridiculous, growth is not going to stop. Of course, he was quite correct in the short run, and he was quite wrong in the long run.

B: So you actually think Florida's growth will stop?

O: Of course.

B: How will that happen?

O: Not only Florida's growth, but the world economy. Florida just tracks the rest of the country, partly driven by ups and down of tourism. Right now we have some cutback in the economy, so Florida cuts back. If you calculate the renewable emergy carrying capacity of Florida, it is 15 percent of the present. By the time the world fuels are too expensive, Florida economy has got to come back to 15 percent. That means you cut the standard of living to 15 percent or you cut the population to 15 percent or some combination of the two.

B: Could you explain that? That is intriguing, and I was going to ask you about that. How would you create an emergy model for Florida?

O: We have, and in fact, it is in the back of the Florida book.

B: Okay, that is called Environment and Society in Florida by Howard and Elisabeth Odum and Mark Brown.

O; Right.

B: What did that basically look like? Can you describe what the emergy evaluation for Florida looks like?

O: Sure. It shows the components of real wealth, where they are coming from. Again, most of it is fossil fuels, directly or indirectly, that is, either they are coming in as fuel or . .

[End side 2, Tape A]

B: This is side one of tape two, and we were just talking about an emergy evaluation of Florida and what it looks like.

O: (Refers to a diagram.) You know the word carrying capacity is an old wildlife term, and it refers to how many quail or turkey you can support in a given area. It refers to something that is at the top of the food chain, but also how much the bottom can carry on the average. But with carrying capacity of people, it is not only what the area of land and the waters of Florida will carry, but it is also what you can bring in from outside, that is, fuels in this case, pipelines of gas.

B: What does it mean that we have a 15 percent carrying capacity?

O: It's what you can do if the fossil fuels and minerals were completely gone. We can do all the things with sunlight and renewable energy. We can make fiber, food and housing, motor fuel, and all those things, but you cannot do them all at the level of the present society. You have to cut back to 15 percent.

B: 15 percent of the current level?

O: That is right. But that is not going to happen in a big hurry. It is going to drop a little bit, so if your population goes down at the same rate at which your real wealth use goes down, then you can keep the same standard of living.

B: Maybe this would be a good time to talk about the fossil fuels that we know exist in the eastern Gulf of Mexico that are not being drilled now.

O: Back in the days when I was at Texas, I was director of the Institute of Marine Science at Port Aransas. It is a branch of the University of Texas at Austin. Many of our studies of the Texas bays had to do with the processes that formed organic matter that then was covered over by sediments, which makes oil. One of the things

we learned there and published about was that any kind of extreme knocks out the consuming organisms and leaves behind the organic matter to form oil. So oils tend to form where there are extremes, and one is extremely briny places--salty, like south Texas and the desert areas of the world. Another is in the river deltas. In the river deltas you get the surge of fresh water with organics, and then it is salt, and then it is fresh, and then back to salt. Consumers can't develop, and so the production of the plants is not eaten by animals. These are places where oil forms. Oil areas that generate and retain oil are those that have clay sediments, not porous limestone. Coral reefs do not form oils normally because they have good consumers. Also, they are porous, and do not collect oil. Where there is high diversity you do not have any extremes. That is why the Bahamas have turned up very little oil. Peninsular Florida is the same way, except for the small Sunniland field.

B: Which is in the Everglades and southwest Florida.

O: It is very tiny, and it, too, had a briny condition that was there for a period.

B: So you do not believe there is as much petroleum?

O: I do not think there is in the limestone and sandy sediments of Florida. As soon as you go west, there is--where there are river sediments from the north--obviously, the Mississippi and the Apalachicola River. From there south is, of course, where they are going to drill next, according to the new plans.

B: How about natural gas? Does that follow the same pattern?

O: Yes, but it is much less. I think internet discussion groups are bringing our fuel limitations out very well, and the public is

gradually beginning to hear it even from George W. Bush (U.S. President, 2001-present), that in North America, the gas is going to run out soon. Too many new developments are using gas, and when they cannot find it, and they are, of course, going back to coal. But with coal it takes more to process it and to keep it clean and all of that. The thick seams of coal, when they are gone . . . you use thin seams of coal and they do not give you much net energy. In other words, we keep using poorer and poorer deposits. We have to put more back into getting them. What you can get beyond what you have to put back runs everything else. If that gets less, the standard of living has to come down.

B: So you think we are making a mistake building new coal-fired plants, such as the big one in Jacksonville.

O: No, I do not think so. I am presuming they will have to take care of the environment better than in the past, but the maximum power principle says that you cannot not use energy. If you do not, somebody else will overgrow you and go do it. So on that, (Richard M.) Nixon (U.S. President, 1969-74) and (George W.) Bush were right. But at the same time, you do not do it wastefully, in such a way that you hurt the environment, because that cuts down on maximum power as well. We need to keep the environmental production going while you are moving the fuel. Turning loose private industry to maximize their profit without incentive is not the way to do it. Tax incentives can help the environment contribute its real wealth.

B: What do you think about liquefied natural gas and the potential of moving that into Florida?

O: I just came from Alaska. I was there a week with my daughter. Of course, gas development is in all their newspapers too, whether to take their north shore fuel and run it down the present pipeline, liquefied, or whether to send it by ship. This liquefied gas is refrigerated in order to compress it. It takes a low temperature, and this gives you, essentially, a floating bomb, so people do not normally want to move it to anywhere around an urban population. I cannot think of any place on the west coast where you would want to have one, and the same with Florida. I doubt if the politicians would allow it once the dangers were known. If the stuff gets loose, it may blow up, or it may suffocate people. It's just too dangerous. So that is why these plans to perhaps have LNG energy come in from wherever it is, the near East or Alaska, wherever, will not be permitted.

B: Or the Bahamas, right?

O: One plan brings LNG into the less populated Bahamas and then through a pipeline down under the Gulf Stream, which is a mile deep. It is a huge expense, but that kind of thing is being discussed. Again, emergy is the way to determine which of these alternatives is better.

B: But you do not think it will be liquefied natural gas for those reasons you just stated?

O: No, I did not say that. I am saying that whatever is necessary to use the fuel with the most net yield will prevail. People are going to use it. As to whether--for example in Alaska--whether they use ships from Alaska, or run the gas back down through Canada and the McKenzie Delta, a long, expensive new pipeline . . . You may have

to do an emergy evaluation. At the time the existing Alaska pipeline was being discussed, Mark Brown did an analysis of whether it would yield net energy, and he got a ten-to-one yield ratio, which is very good. Therefore, we predicted it would be a success, and it was. We have had a very good record predicting with emergy evaluation. For example, it predicted that the oil-shale development was not a net energy yielder, as we testified in Congress in 1975. They ignored us and went ahead with it. Both the federal government and the oil companies lost about $3,000,000,000. It did not work. There is no way you can tell whether something will work unless you do an emergy evaluation, because the money does not cover all of the aspects.

B: Could you describe your emergy evaluation of Florida Power's nuclear plant at Crystal River?

O: There was a period when Florida Power had a very environmentally-oriented policy. It had a vice president dedicated to it, and had a whole lot of contracts with us and other universities to understand what they were proposing in building that nuclear plant and releasing the hot water. We did things like measuring the estuarine productivity; we measured the day-night rise and fall of the oxygen. So we measured the productivity of the areas that were getting hot water. The trouble was, it was not steady hot water because they were turning the plant on and off. They had to because that is the nature of power plants and repairs. An estuarine ecosystem adapts to steady hot water, as in hot springs. The productivity of the grass flat ecosystems was about half, with environmental cooling.

B: Just the switch in temperatures?

O: Yes. On the other hand, the estimated emergy of environmental damage off somewhere, let us say Buffalo, New York, where they are making steel for the cooling towers, was even greater than using the environmental cooling. In other words, letting the hot water go on into the grass flats and having less productive grass flats by half, was less emergy damaging to the environment than building a cooling tower to prevent it. People building the cooling towers were not figuring on the environmental load of all that construction somewhere else. People often view on too small of a scale. Our result caused a reconsideration of policy which held up that cooling tower for some years. But then the national policy to do it irregardless took over, management of the power company changed, and they went ahead with cooling towers, and added some more nuclear power, and so on. We evaluated the whole area including the intake system sucking in water from offshore, causing a canal ecosystem full of batfishes. It was interesting the way ecosystems reorganize to fit the new conditions. Part of the problem with the environment is that people try to go measure the impact right after some change is made, and you should not do that. Wait three years and see how nature has built in response. So there emerged a principle to contrast short-term evaluation and long-term evaluation.

B: Are those fishes there now, is that new ecosystem there now?

O: Well we have not evaluated it since. I put in proposals to take another look, and a summary, but the later administration of Florida Power was not interested. Of course, they had serious problems with CEOs, and embezzlement.

B: The upshot was they did not do it, what you proposed.

O: No. They did not find a way to use the hot water as a coastal resource. They did the more expensive thing, not based on the evaluation that is possible if you use emdollar evaluation.

B: Do you think the environmentalist side on that issue was really not...

O: In that case it was not, it was small scale, small myopia.

B: I guess we will go through some of the big Florida projects that you worked on. I was curious if you had ever worked with Disney or for Disney.

O: The Center for Wetlands had a project that developed Disney waste wetlands, but I did not have much to do with that. I brought in a deputy, Ronnie Best, and turned a lot of projects over to him, particularly when I was on sabbatical. I went off to the LBJ School of Public Affairs in Texas (Lyndon Baines Johnson, U.S. President, 1963-1969), again to develop our emergy concepts, in 1982, so that particular project was done by someone else. Mark Brown might be able to tell you more about it.

B: So you did not work with Disney then.

O: No, not personally.

B: Okay, how about your early evaluation about . . .

O: Let me say this about Disney, that when they put in EPCOT (Experimental Prototype City of Tomorrow), they were scanning universities for inputs, and we proposed putting something different from what they wanted. They wanted a village of the future with more and more technology. We proposed a village of the future for living with lower energy when it becomes necessary, and they turned it down.

B: I bet it was very interesting.

O: They thought it was nutty, I suppose, or they knew their public better. The public is not ready for that. The public is going to be ready for it soon, but they do not know it yet.

B: When they are forced into it.

O: You cannot use questionnaires to ask people in order to find out what the public policy will be because it changes as a whole, and they all do it together. They flip together. That is the power of the social system, and again, an example of the pulsing impact. In regards to the cross-Florida barge canal, the government spent $500,000 on a committee and on questionnaires to get a popular view instead of doing an emergy evaluation.

B: And you were involved in that?

O: No, we were opposed to it. Mark Brown and his associate Susan Carstenn have done an emergy evaluation of the cross-Florida barge canal which they are about ready to publish. Like a lot of other things where the public is split, it is not a clear-cut difference in emergy value. It is one where the values of both are similar. Apparently the public's opinion is tracking the real value in that case.

B: So you were part of the effort to oppose the cross-Florida barge canal in the 1970s?

O: I was in North Carolina in 1969, and Ariel Lugo was very important here. He is now director of the Institute of Tropical Forestry in Puerto Rico where we interact, but he was here in botany. He brought me down to give an evaluation lecture, make our

contribution, and sign letters. All that was successful, and Nixon stopped it. So that was our primary involvement then.

B: What was the purpose of doing an emergy evaluation of it now?

O: It is whether to remove the . . .

B: Oh, the Rodman Reservoir. Okay, so not whether the government should have done the whole . . .

O: No, it would not be hard to show that the project was a net loss. After all, it started as a way to avoid submarines in the Second World War. It disrupted major ecosystems for little purpose.

B: Back to Disney, it seems like it would be interesting to do an emergy analysis of Disney itself.

O: No, we have not done that one, and you are right, it would not be hard to do, I think, if they would give you the numbers. What do you need for one of those evaluations? Well, for one thing, you have to have all the costs involved, the flows of money, because that identifies things that were purchased and brought in. Then you have to have the actual fuels, electric power used, lands used, and environmental measures. There is the number of tourists and the amount of money they brought in. We have done emergy evaluations for the whole state, and we have done it for about ten counties and sixty nations.

B: Well, if you have done it for the Civil War, you can do it for Disney.

O: That is right.

B: Could you talk about the early evaluations of Cape Coral, Marco Island, Naples, that southwest area?

O: At the same time we got our Center for Wetlands money, we also got the attention of Nat Reed and his aid, George Gardner.

B; So this is about 1973?

O: Yes, a little later. They picked up on all this and set up a set of federal projects and got state planning involved.

B: Was that when Nat Reed was working with Nixon?

O: No, he was under-secretary . . . who would that be under?

B: Nixon.

O: We had a whole set of projects which we called the south Florida projects, about a half a million dollars, worth nearly ten times that now. We evaluated environmental issues in south Florida and we picked several counties to emphasize, Hendry, Collier, and Lee County. We also did the Keys, and Monroe County, the Everglades and Everglades Park, and Lake Okeechobee, and the Kissimmee River. Our reports were probably ahead of their time, and the present revisions now going on in the Everglades are doing the things we recommended. Our emergy evaluations were not yet called emergy and publication was delayed. We had problems because we did not know how much solar energy was equivalent to fuel energy, and it took us until the 1980s to get that clear, to get the numbers right. So we have 2000 pages of unpublished reports, a lot of evaluations. For example, Frank Nordlie in zoology helped us edit one set of these, and I dug those out last year and put some up for possible publication with the corrected values, now that we know how to convert solar energy into higher level energy (40,000 solar calories per coal calorie). Over-evaluation of the potential of solar energy to replace fuels is hanging up the solar energy policy of the world. People do not realize how dilute solar energy is. At the solar center here, we have been off and on arguing with them, or at other times

collaborating with them. They put emergy evaluation in one of their handbooks. We evaluated Florida's energy future with our state energy project.

B: What is the answer?

O: You cannot improve on photosynthetic conversion to biomass. The most efficient conversion possible was achieved with a billion years of evolution. If you work long enough on solar technology, you are eventually going to get that same conversion efficiency. It takes many joules of sunlight to make one joule of fuel, and that is not something you are going to be able to improve. Solar technology tries to take the solar energy and jump right directly to electricity. You can do it, but you put so much emergy back into the process that you do not get any net. That is in our books (refers to page in Environmental Accounting). People are torn on this, so . . . . . that no one will believe us.

B: What was controversial about these south Florida reports that you did?

O: Well, for example, with the Kissimmee channel, Tim Gayle did his thesis, a beautiful job of showing how, in channelizing the Kissimmee River, the water that used to take three months and arrive after hurricane season would come zipping down and arrive in the hurricane season. Then the excess had to be dumped in the ocean. So all that water was wasted, all the productivity of the wetlands, and all the filtering.

B: So, all the things we know now, you guys were saying in 1973.

O: Yes, in 1976. That is where it came from. Now that policy is straightened out. They could have put the river back easily by just

putting a set of dynamite charges along the banks, blowing it up, and let the water reorganize it, but instead, they are doing it by bulldozers step-by-step. Again, people do not have confidence in nature's self-organization, which is what you are going to have to fit anyway. So why spend all this special energy trying to manage the change at extra cost?

B: What were some of the things you found out about Cape Coral and Marco Island and Naples?

O: Well, at Cape Coral the developments cut deep channels that undermined the groundwater, losing land values.

B: So that had already been done by the time you looked at it?

O: Yes. We showed what is wrong with it and evaluated the lack of fresh water. Maurice Sell's studies discovered that the wastewaters of Naples, that they were turning loose from the treated sewage, were going up in the mangroves, and the mangroves were profiting by it. They were not hurt by it, and they had faster growth. It was another demonstration that wetlands, marine wetlands in this case, are a good way to ameliorate this big problem that Florida has, and still has, of excess nutrients.

B: So, in Naples, this wastewater actually helped the mangroves?

O: Yes.

B: I do not quite understand about Cape Coral, though, is it different there because these are manmade?

O: As Flora Wang in our group showed, if you cut a channel with Florida's porous sands, which have 20 to 30 percent pore space, or limestones, then the water table is dropped for a mile away. So if you have a deep channel, you have dropped the water table,

therefore the plants cannot reach it, so you have turned it into a desert. The rain that falls on it does not hold and sit there, it just shoots down to the bottom and out. That is not the proper way to use valuable water. When you drain, you turn the soil climate of south Florida into an Australian hydroperiod, and so things like Melalucca prevail. Exotics, by the way, are one of the big issues that I did not put on my list of things to discuss in this interview. Exotics are one of the best tools that nature uses to get productivity out of areas that have changed. Unless you can change the regime back to the way it was, you need to learn to live with exotics. It is doing something that is giving you a productive result. The first time an exotic moves in, it may be a monoculture. How do you maintain a higher diversity? How do you eliminate the excesses that cause exotics to be monocultures instead of just adding to the diversity? These are appropriate questions.

B: Does this mean you think we are making a mistake spending so many millions to take the Melalucca back out of south Florida now?

O: The way it is done, probably yes. You have not really changed the conditions. It is too bad we did not build Florida structures up and let the water regime stay the same. It is too late for that right now. You already have too much housing at the ground level, and now the water table has to be below that. That makes a semi-arid soil climate that favors exotics with the strategy of transpiring and using up the water to make the soil dry again. It adapts to wetland conditions by wasting the water, whereas the original cypress has leaves that reflect the infrared solar energy and saves the water and keeps soils wet. That is why if you want a headwater, then you have

to keep the pond cypress, not bald cypress. A pond cypress regime is necessary if you want to continue to have a headwater. That is why all of the headwaters start with the pond cypress: the Okefenokee in southern Georgia, the Green Swamp, the Withlacoochee, and the Big Cypress headwaters. Everywhere all over the state, preserving the headwaters of swamps maintains water because that particular vegetation does not transpire, it does not grow rapidly. It saves water instead.

B: So the exotic species are not as bad as the current scientific community would make us think that they are?

O: Well, it depends.

B: There seems to be a real eradication effort state-wide.

O: Some is misguided, particularly in aquatic plants. The proper solution is to cut off the nutrients, that is to cut them off at the source. People are beginning to catch on to this. There are more recommendations, as with the Everglades, to put in strips of wetlands to catch nutrients. Accept the principle that you have to have a eutrophic monoculture wherever there is an excess, and you have to save areas for that. Then the water coming out of that zone will be oligotrophic and usable in the more normal way. Unless you can stop the nutrients at the source, you have to have a eutrophic-type wetland to catch them. Instead, we have a destroy and replant policy. It is absurd, going out poisoning or cutting to remove them. Of course, they will just grow right back because you have not changed the conditions. Nature is trying to tell you something. Nature's way of getting rid of any excess is to bind it up into peat. That is done with solar energy that does not cost you anything, and

for this exotics are useful, but it does take land area. Land is the problem in the Everglades and everywhere else. You do not have much land area left in which to catch the nutrients. You sure can go back and stop this by putting regulations or something on all these companies that spread fertilizer and poisons over the grass, and get people to xeriscape and use a diversity of natural species. It is in the news, even yesterday's newspaper had an article on it. People are coming around to it.

B: What would have been the better way to handle the aquatic plant invasions?

O: Well, as I just said, to cut off the nutrient source in the waters by putting a strip of wetlands and by stopping it at its source. Consider the septic tank wastes, let us say, that are going into some lakes and turning them eutrophic. If you do not mind a eutrophic lake, it is useful, like a sewage pond in Texas, but if you would like a lake that is clear water for other purposes, that does not have great oxygen swings, then keep the nutrients from getting that far. The aquatic plant people--I do not know where they are coming from, and they are just wasting money.

B: They are wasting money by trying to poison the plants.

O: Or to remove them.

B: Or remove them.

O: Instead of getting at the fundamental, which is change the nutrients of the water flow.

B: Some of these people you are talking about are people on the IFAS faculty.

O: No, I am not pointing at anybody, I am talking about the policy of the state in supporting these big projects, aquatic plant projects. I have not kept up with who is continuing the poor policies. I would rather say that people are catching on, and it is gradually about to switch. Ecological engineering education gives you the proper concepts, but puts out only a handful of people each year, whereas you still have biology departments everywhere putting out ten or a hundred times that many people. What are they taught? Well, they are taught no-change conservation. There is a society of restoration and it does some of the same things the ecological engineering society does. Except the word emphasis is wrong. Restoration implies you are supposed to go back to something. If the conditions are going to be the same as they were, you could go back to it, but if the conditions are going to be with humans and environment and higher nutrient levels, then you have to have a new system, and that means new species and new designs, and the trick is how to get it all to maximize the landscape productivity. We just have too few people with enough environmental science to go into these jobs, and it takes others five to ten years to catch on.

B: We talked about the ivory bills and the Carolina parakeets, and you know, is it ever possible or is it ever a good idea to try and reintroduce species?

O: Sure, if you have got a habitat that will support them. The Carolina parakeet, according to the early ornithology books, got a lot of its nutrition out of the cypress balls, but all the great cypress forests were destroyed except remnants like the Corkscrew Swamp and one or two along the Tamiami Trail. We hardly even have a

demonstration for the public to see, so I do not think there is enough habitat for the ivory bill right now (which could be reintroduced from eastern Cuba). There are so many parrots and parakeets loose in south Florida, I keep thinking that eventually one will catch on, that can live under the new circumstances and spread. I am in favor of exotics that are adaptive.

B: You are speaking of the feral parakeets.

O: Yes. There may be somebody who knows if some of these new ones are using cypress balls or natural sources of food, or whether they depend on people and their fruit trees.

B: I wanted to go back and finish talking about southwest Florida. How about the work you did on Marco Island?

O: Diana Steller did a lovely thesis on it, and Marco Island was in Maurice Sell's dissertation. At that time the developers had a trick: they would cut off the water table to the mangroves, then they would say, "see they died, there is nothing we can do about it, now we have to develop it." They did that on Marco Island, so they put up a few high rises, and then people would come down and they would say, oh look at all this space, and look, my kids could canoe out there in the swamps, and this and that. Of course, they would buy condominium deeds, but by the time they got there, instead of one, there would be ten. All of a sudden, in order to have all those cars, you ended up paving the place over. We did an emergy evaluation of that particular pattern. (Emergy was still called embodied energy then.)

At the same time, there was still rancor about the herbicide agent orange in Vietnam. In the 1970s I was on the committee of

the National Academy of Science to evaluate herbicide impact, and the Vietnam war was still going on. That would make it 1974, I think. We all went to Vietnam and did experiments and sprayed agent orange and studied its effects and how long it lasted. It was a $2,000,000 Department of Defense project involving many universities and people. Our part was the mangrove study at Vung Tau. It was pretty interesting field work. You would be out there, protected by two soldiers standing by with machine guns in case there were Viet Cong. We learned later that the place we were studying had an unwritten agreement that they would not fight in that area. It was used for recreation for both sides. So anyway, there was a lot going on.

B: What did you learn about the effects?

O: We learned that the stuff did not have any long-term staying power. It did not last, but killed the mangroves outright. The monsoon-adapted trees inland would come back after defoliation because they had storages. But mangroves, since they were evergreen, did not store any energy, and if you killed them, they would not come back. We recommended that they replant them, and use bombers to bring thousands of seedlings from Thailand and drop them into the place. The south Vietnam members that were on our national committee said, "no, we want to turn it into rice paddies." So we did not recommend that, but we did evaluate it. Mark Brown evaluated the whole war. He showed that of the emergy running the war, ten times as much was coming from the U.S. as from North Vietnam. Some of that same energy was being used by the other side to fight back. It was an incredible evaluation of war--the first

really good one, and of course, we have since evaluated the Civil War and others. In Vietnam all the refugees went into these defoliated areas, and they cut down all the dead trees to make charcoal, and then they started on the live trees. What had been a partially damaged mangrove area was stripped bare. There are forty species of mangroves in southeast Asia, and in this country there are only four. The devastation was not only the Americans spraying, but also the refugees stripping. I went to an international conference in Japan several years ago and heard a paper by the Vietnamese on what they had done with that land, the north Vietnamese, after they took over.

B: What did you find?

O: They did not turn it into rice paddies. They made plantations of mangroves. Instead of natural mangroves with forty species, they set up forestry plantations of one species.

B: What did they use them for?

O: For wood, charcoal.

B: So it was the federal government. . . . back to the southwest Florida studies...

O: The reason I got on that was...

B: The mangroves, right.

O: We did a field study on Marco Island. Howard Tees from Miami took agent orange and sprayed a plot. One of the two ingredients in agent orange was illegal, so he sprayed with the other legal herbicides. He lost interest, and so we did a study of the area that had been killed. That was one of the many things that was done there by Maurice Sell. The rate of recovery was rapid--we got a real

detailed view of how quick it could be restored if the seeding source is there.

B: But you said initially it was a developer who illegally sprayed agent orange on mangroves down there?

O: No, you misunderstood me. It was a scientific experiment. Pseudo-legal. We did not do the spraying, but we did the measurements.

B: And the south Florida project, was it funded by the federal government?

O: Yes. The Department of the Interior under Nat Reed. It was two-thirds federal, one third from the Division of State Planning, and that probably was Earl Starnes.

B: I am still trying to get at what was controversial about your reports. Is it that the public was just not ready to hear these things? Were the developers angry?

O: No, they were new ideas that took time for the agencies to absorb. I do not think the full impact ever reached them. Society published things, but it was going too fast, we were doing too much. As part of the project, we put out four public affairs booklets. They talked about growth and non-growth, and energy, embodied energy (emergy), and planning, in the context of those counties.

We had splinter projects. Naples, Florida, has a small river down the middle called the Gordon River, and they wanted to dredge and channelize it. It was controversial, so the county put out an RFP (Request for Proposal), asking people to bid on it. So we bid on it, with my hydrologist collaborator, Wayne Huber. We did not know that we were bidding against Art Marshall, which was too bad because we approved of what he was trying to do. We did a

real first class job on it, showing how the water of Naples was based on the water in the surface sands, because the deeper ground has salt in it. Deeper sediments were flooded in the Pleistocene Era. Lands with elevation below twenty-five feet, in the whole state of Florida, have groundwaters that are not suitable, they are too salty. Naples was using the water in superficial sands. The rain in one year was used up before the end of the year. The solution was not to drain it, not to dredge. If you dredge that river channel, you would have sucked the water right out of their water supply. It was not hard to prove that. That got us down there, and we saw instances where development had built the roads up through wetlands, and thus preserved the wetlands rather than draining them. We developed a whole lot of guidelines for the state, and put them in a handbook of wetland management that has been reprinted a couple of times.

B: So you were listened to in that case.

O: Sure, I did not mean to imply that we were not listened to. The energy crisis of the 1970s came and went, and the minute we started talking about eventual economic leveling and coming down, then we started losing people, then often they'd throw everything else out. I remember one time, my brother tried our approach in a lecture he gave in New York. He called me up and said it did not go over, and he was not going to use that any more. My response was, what has that got to do with anything? Are we in the public relations business, or are we trying to find the truth and maybe shock people into taking notice of it? Of course, the practical path is somewhere in between, I am sure.

B: So you are not in the business of making people happy or telling them what they want to hear?

O: We could have done better, I am sure, but we were pulled in too many different directions, but maybe not . . . who knows? Our preliminary reports were extensive, but only part was finally published.

B: I am going to turn the tape over now.

[End of side 1, Tape B]

B: This is side 2 of Tape B.

I was just going to ask Dr. Odum about the Keys part of the south Florida study.

O: Jim Ruttenber, who is now professor of environmental medicine at the University of Colorado, came down from Emory and did the Keys, making our embodied energy valuations there. It was in his dissertation at Emory University. Again, I do not think we adequately ever published all these things because we were still struggling to get the correct conversion of solar energy to fuel. I guess there were about fifty theses and dissertations completed. Even now it is possible, and perhaps we should go through and pull out important conclusions. Certainly the main ideas went into the intellectual community and did spread.

The coral reef off the Keys is deteriorating. Dredging up and down the coast is making waters turbid; of course, corals require light, and they are shaded out. They have been hit with all kinds of over-fishing. Our student Tim McClanahan showed that if you over-fish the larger fishes like the triggerfish on reefs, which are really managers, the balance of the different things falls apart, and the urchins overeat and run wild. The reef collapses, so to speak, and becomes a weedy bunch of struggling organisms (the way many people think of ecosystems) instead of a very highly organized and coordinated network, which is our view of it. I saw the reef again a couple of years ago, and it hardly looked like a coral reef. It is covered with patches of dead stuff, algae, and so on. Florida's environment is deteriorating badly because of the eutrophication and the adding of the organic matter which grows turbid microbial

populations instead of clear water. The self-contained reefs have a self-contained nutrient type of cycle; photosynthetic Zooxanthellae in the corals, and their food chains, all in clear water, take advantage of the currents and wave action. Florida has always had red tides, but runoffs from land are causing brown tides, and blooms of new microbes are becoming dominant. A lot of it is tied to the increasing levels of civilization dumping organics into the waters.

B: But you also mentioned, it is over-fishing as well.

O: In the coral reefs, we were fortunate enough to study an essentially virgin coral reef at Eniwetok in the 1950s. It is one where my brother and I worked together, and we got an award for it. The atoll had been ten years without any people, and underwater was like the very best of the kinds of pictures you will see on television, with large fish schools and highly diverse and beautiful patterns of corals, reef algae, and diversity.

We took one of those Windjammer cruises once and went to the different reefs in the Bahamas, where you stop and swim, but you hardly see a parrotfish. And those you see are deathly scared and swim away. Most people, when they go to Cancun or somewhere, do not see a really good coral reef, they see paltry remnants.

B: What will be the impact of the loss of the coral reefs?

O: To understand, we use the concepts of maximum power. An economic system with a lot of fuel that knocks out the environmental system prevails because it has more power than the environmental system had by itself. The long run effect, as fossil

fuels are cut back, and all kinds of efficiencies and economies come in, will be restoration, if you can manage to hang on to some remnants now. That is why it is so important to protect what you have in the way of reserve areas to reseed ecosystems, so they can come back. There is optimism for the future of the environment, but only if we reduce population as fast as the resources for the economy decline. Environment will be protected if we reorganize around less fuel-costing transportation.

B: I would like to come back to that at the very end, when we talk a little bit about the future. I wanted to ask you, did you do very much consulting work on behalf of developers or the development industry?

O: I made a policy never to consult, except to give lectures. I will take an out of state honorarium for giving a lecture, but I never consulted. It did not seem like it was right. If I am paid by the state to try to find the right answer to all these controversial issues, I should not be taking money from either side. Except from the public, except for formal research projects through the university.

B: When you did the Florida Power study, that was on behalf of whom?

O: That was a contract with the university. You know how grant and control research works at most universities. Most of the money goes for students, equipment, travel, and overhead. If you are on nine months contract, it may pay some summer salary at your regular rate, but normally there are no honoraria, or salary increases. Results are published--open to the public.

B: So you did not work very closely with developers during these times. I know you said you have had students who you have watched go out

into the world with their great ideas and what they have learned, to work for either government or private industry, and that that sometimes has been a disappointing experience. Could you talk about that experience?

O: Well, in a typical case, my student Scott Nixon, who graduated from North Carolina, went to Rhode Island where they said, "if you want to get tenure here, you quit doing that energy stuff and start doing your phytoplankton ecology." They forced him to go back to smaller scale. Of course he did, and he was head of Sea Grant with a very successful career there, but he has been, like the rest of his field, forced to work at one scale too small to answer the larger questions or predict or manage. The same thing happened with Walter Boynton. He had done the Apalachicola River in the Franklin County energy study involving all the questions of dredging that river, saltwater passes, the oyster industry, and the way it was courting troubles with disease because of the salinity change, and all that. So he gets up to Maryland and they tell him, your major professor may be able to do that kind of stuff, but you cannot. Quit this nonsense about evaluating the economy and the environment and start studying the animals. People can be limited by the framework of orientation of their own training. Some were small-scale trained, for example, chemistry and biology. Scientists of our time are taught to look smaller to parts for answers about a system. Biology was bad enough when I came along as far as its scale of interest. I was lucky to have a major professor who was not so confined because he had not been trained just in biology. Then, the world went to molecular biology, which is an important field, even

while I was at North Carolina that was happening. But to be a good molecular biologist and take all the courses that go along with that, it automatically squeezed out hydrology, economics, and geology, and all the things you need to do to understand anything about environment. It is even worse now, and some environmentally illiterate people are coming out of biology departments and being hired by environmental agencies.

B: All those things you mentioned, the human and the microscopic, it all seems to be coming together in the Chesapeake Bay and in North Carolina with this issue of pfiesteria.

O: That microbial bloom is one example. While we were at a Beloit College workshop this summer, we made a simulation of it using the object oriented program EXTEND, to make very attractive little icons on the computer screen, and when you connect them up it simulates their growth and toxic actions. My former associates, B.J. Copeland, who was one of our best people when I was director at the University of Texas Marine Institute, became head of Sea Grant there at North Carolina State in later years. Pfiesteria turned up, and some lady used pressure on the legislature to get together a half-million dollars for research.

B: Joann Burkholder.

O: You know about it? There was a book written on this recently. I guess Copeland's job was to try to get the research done, so he wanted to spread the money among more than one investigator to get certain further things done, but she used legislative pressure to get him fired. That is a nasty story in North Carolina. There was an

article recently, putting that book down, so I do not know the latest on that one.

B: It seemed to be a very hysterical sort of a book, and it was unscientific. I remember reading a review of it where the writer, for example, described her fiery blue eyes and described her physically, so you can kind of see that it was very dramatic. I did want to ask you about the media, so maybe this is a good time to ask, I will ask you when we come back. [Tape interrupted.] We were just talking about the rather sensational book that has been published about pfiesteria. That was leading into a question about how the media covers environmental issues. Particularly in Florida, how do you think the media does covering environmental issues? How does that hurt or help public understanding?

O: There are individuals in the media who are well-trained in environment, but in general, most have had training in economics, but not the environment, and have no judgment about scientific issues. They simplify by seeking adversarial people when they should be discussing all the factors and people who have solutions. Instead, they try to get opposite sides to argue and create emotional attention. I think the media coverage is not good at seeking answers in most cases. The public has the same problem in that when they go to high school or even college, they may get some economics and that is all. They do not get economic and environment understanding in the proper perspective.

B: It sounds like you are also saying the issues are perhaps made too black-and-white.

O: Often they do not get the right issues, they create false issues. An example, I am not sure it is related to Florida particularly, is Biosphere 2. We had four of our students participate in this. You know what I am talking about?

B: Yes, but explain Biosphere 2 for the tape.

O: Biosphere 2 is a 500 million dollar project that was set up in the mountains, 4,000 feet elevation, near Tucson, Arizona, funded by one of the billionaires. A very remarkable set of people developed a project and had splendid engineering and several had science backgrounds. They built this giant glass structure and people moved in for two years. They overdid the public relations and caught everybody's attention, and to some extent, imagination. Many scientists who were small scale did not understand the significance, and I suppose were jealous of the money going to others. Because some of the people there were not fully trained with science degrees, they just blasted them. The newspaper people took that point of view and just massacred them and created an entirely wrong image. Two of the people who were inside afterwards came here and did Ph.D. degrees: Linda Leigh and Mark Nelson. I worked with a Harvard faculty member in editing a book recently published. This volume pulled the best of both groups, the first team of people who were in there plus the team that followed when the billionaire got improperly turned against the original team because news people said it was terrible. It was not. They walked in one day and threw everybody out and threw some people in jail and lawsuits followed. Colombia University ended up taking it over, but they changed the concept to a growth chamber

instead of it being a self-organized living model of the biosphere. It needs to become a national lab, but it is beautiful work, and by putting this book out, we documented it, but it did not change the public image. The media are not capable of handing environmental things because they take specialists and their prejudices and spread them out, and try to create controversy with it, and leave people with the wrong impression. It is really a sour business.

B: What is the answer to that? What is the solution there? How do you communicate ideas?

O: First, require journalists to have a course in environmental science and economic balance. Well, where are those courses? We give them to a handful of students. We have written the books for schools and colleges to do it, but they are not being adopted because people who are going to adopt them don't see the need for systems views and principles. They don't believe human affairs are controlled by these principles.

B: What are some of the important lessons that came out of Biosphere 2 that you have put together in this book that the public should have known about but never found out about?

O: Well, it is a model for the whole world. Like the present earth, it had more respiration (consumption) that is, more carbon-dioxide generation than it had plant production at first. Therefore, you had an accumulation of carbon-dioxide with all those associated properties, waters getting acid, and the oxygen being embedded in ocean, soil, and concrete, and used up in the process. There it happened quickly because the system is small, only three acres in size, whereas the whole globe takes many years to fully respond.

Very quickly, it ran out of oxygen, and management had to move in an oxygen tank truck. It is the most beautiful demonstration of how beautifully our earth is self-organized by its many ecosystems and the way they interplay, the ocean and the atmosphere, and the coupling that has developed is self-organization over billions of years. It showed how much energy and genetic diversity it takes to try to even simulate enough of an earth to support eight people that were inside.

B: I guess we will go back to some of Florida's big environmental issues that we had to finish talking about. One was Lake Okeechobee. Did you do very much work there?

O: Yes, that was part of our Kissimmee, Okeechobee, Everglades project. We made a valuation of it and we simulated and showed how the phosphorus was increasing its turnover time, and what would be necessary to keep it from becoming more eutrophic. It was all shown in the thesis of Tim Gayle way back in the 1970s. When the hurricane drowned those people before the Corps of Engineering put up its levees, it was because the farmers had put up a flimsy dike that held the water back before collapsing. If that dike had not been there, I think that water would have simply overflowed into the glades. Now, in order to keep water from overflowing or getting too high, they dump it into the sea. That is being corrected now, but they still have wrong plans. We just did a new evaluation of alternatives and distributed it around to all the boards that are involved with this. The plan in 2001 is still trying to hang on to the agriculture just south of the lake, which needs to be a eutrophic, natural absorbing slough. This area is already bounded by ditch

levees. This first sector could be turned over to hyacinths and other eutrophic aquatic plants, let it grab the nutrients and sediment them, which is nature's way. Then the water coming out of that sector would be oligotrophic, which would be the desired original condition. Instead, they are trying to do it piecemeal, setting up some little tiny wetlands, pumping waters here and there, and into the ground and back with all sorts of artificial experiment structures. That area is too deep now, for rooted plants. The peat is nearly gone, and the agriculture has already failed there. The federal government had to buy the sugar last year and support sugar prices above world prices. It is against all economic principles for us to subsidize sugar here just because we do not like Cuba, and Cuban exiles with political power are running the sugar in Florida. It is quite clear what needs to be done, so we interact some with the committees involved, such as the committee chaired by John Marshall, the nephew of Art Marshall. So we are spreading this information around. I suspect they will eventually come around to this plan. It has been my experience that, if we get our ideas and spread them broadly and give it some time, they will usually be adopted. Maybe they have to try the wrong thing first and come back to it.

B: What do you think of the impact of the water management districts on the state, particularly the South Florida Water Management District? How good of a job do you think they have done?

O: Florida is fortunate to have districts that are authorized to manage water, and have some taxing authority, and can try to do something, which many states do not have. On the other hand, the first one

which was set up was mainly aimed at grabbing more water for agriculture originally, and then for Miami. The present plan being implemented gives more water to the Gulf Coast development. Still, there is progress there.

B: Right. So the restoration plan is really an urban water supply plan and not so much of an environmental restoration plan.

O: Partly. They are trying to restore the oligotrophic Everglades. Of course, the cutting off of that water did many other things. It not only gave the Everglades Park this too-much, too-little pattern, but the saltwater moved in all through the lower Everglades and produced dwarf mangroves everywhere. Dwarf mangroves grow when the salt is too high. When mangroves transpire, salt is left behind as the plant makes fresh water. Mangroves normally will have double the salinity round their roots. That is, solar energy pumps the water out, leaving salt behind. But then the salt flushes out through the crab holes. If it gets too salty then even the sun's transpiration cannot pull out water against that gradient. Little tiny dwarf mangroves result; that is what is around the Florida Power and Light Corporation in Miami. We were talking earlier about Florida Power cooling towers at Crystal River. The big controversy with Florida Power and Light at Miami is about whether to put that hot water out into grass flats or build a huge network of cooling canals.

B: That is near Biscayne National Park?

O: Right. So public opinion forced them to construct the canals where water goes up and down, and up and down, down and around. Unfortunately, they paved a lot of it, which is a mistake, instead of allowing natural growths along the banks. That was another

example of a huge expense that was, according to our Crystal River work, incorrect. They could have made some compromise and done better. Anyway, nature tries to organize around human folly, and there has been a crocodile colony growing in there.

B: I have seen it, it is full of crocodiles.

O: O, you have seen it since I have. How many mangroves are in the grid?

B: You know, I did not see any mangroves in the grid. There is no growth on it. There was quite a bit of wildlife, birds and crocodiles, but that was it.

O: Well, nature will self-organize as best it can to fit humans; that is part of ecological engineering.

B: What is the impact of dwarf mangroves?

O: The productivity is a fraction of that in a full-community ecosystem where there are many processes and diversity.

B: One more thing about the Everglades, what do you think of the ASR, Aquifer Storage Recovery technology that they plan to use to store water deep underground to pull up later when they need it?

O: That is the one I was objecting to. They are doing that in place of giving up this small amount of agriculture for a slough. (Refers to Odum's plan map.) See, this would not give up all the agriculture. The plan offers to the remaining agriculture the opportunity to pump their waste into this eutrophic slough, which is cheaper than using technology. About twenty years ago, we published a plan for a eutrophic strip to come all the way down from Lake Okeechobee to Florida Bay that everybody could pump into or pump out of, so this is another version of our earlier plan. It is a way of getting the

nutrients out of the agriculture and into peat on the bottom of this one slough.

B: Again, that area would give you enough storage room for the amount of fresh water they need?

O: It would give you enough nutrient absorption capacity. I think the question you are asking me now is a different one. You are asking whether or not they need the water storing capacity.

B: Well, part of the reason they claim they need it is for the urban population.

O: We did a Martin County report, you know. We have done a number of county reports considering alternatives with our emergy analysis, where they have an excess of water. The Stuart Canal from Lake Okeechobee comes through this county to the Atlantic Ocean. Our point was that fresh water is the ultimate limitation of economic growth in Florida, as most everybody comes to realize. Martin County quit letting that water drain away and set up its own storages for that purpose. So I think I am for any procedure to store fresh water because you can get more total emergy production, more total value, out of fresh water on land, which is what the earth tries to do. The earth brings the rain to land. And keeping it there and getting the good out of it gives you more than letting it run into the sea. But when it runs into the sea, it is not all wasted because it drives currents and makes the estuaries more fertile and does a lot of secondary things. If you take fresh water that has been going into an estuary and then take it away, then the estuary loses about half of its productivity, and its faunas and floras and all those fisheries. There is a principle here that we have not mentioned, that all

energies in nature are in use already. When somebody says, "there is some unused energy, some tidal energy, or wave energy to use," they do not realize that it is in use already, and you are getting the economic good out of it because it is cleaning up your water, giving you life support, protecting your coastline, and giving you fisheries and all these things. You forgot about those. It is like the salmon, if you take the water for the hydroelectric power, you will not have it for salmon, and fertile floodplains. You cannot have it both ways.

B: That reminds me about the politicians in south Florida who would eye the Suwannee River and say that water is not being used.

O: The Suwannee River already generates environmental value with economic value within its watershed and at the coast. Water coming out of rivers turns to the right in the northern hemisphere because of the Coriolis force. That means they tend to swing north on Florida's west coast, but sometimes it comes south to Cedar Key. Keeping that fresh water enriches, but there are several different patterns to which ecosystems adapt. With pulses of floods in a big river, you get low diversity but high productivity, so you get oyster reefs and an oyster industry, Apalachicola Bay, for example. If it comes out slowly and gradually, as in spring fed rivers, then you will get a high biotic diversity. Then you will get grass flats with many species, and not so much of any one. Now both patterns are valuable. One is more stable and aesthetic; one is a yield system.

B: So which is more valuable?

O: You have to evaluate with emergy-emdollars. In those two cases they are both going to have high values. That is where nature has put together different adaptations for different circumstances.

When you first knock out an ecosystem with changes, you have removed its production of real wealth. After a while nature organizes something else there that builds back some value production.

B: How would you analyze something like that if you consider the huge human population in south Florida looking at the Suwannee River and weigh that against . . .

O: For example, you get more total wealth developing two areas than diverting resources from one to overdevelop another. The U.S. cut off the Colorado River water going into Mexico. California overdeveloped, leaving other states underdeveloped. Water illustrates another principle I have not mentioned. To get the full use out of energies of one level, one quality, they need to interact with an energy of either a lower quality or a higher quality, so that mutually they amplify. Water is a means to attract fossil-fuel investment, and that attraction ratio in Florida now is about seven to one. For every unit of real wealth from nature, on average it attracts seven times as much purchased emergy. For example, fish population develops a fishery industry, and Cedar Key is becoming a tourist center, with money that buys more emergy. So, if you knock out the fresh water, you not only knock out that emergy, but you knock out what it was attracting. If you move it to south Florida, then you are going to lose eight times the amount you transfer. And if you pull it down there, where it is too crowded, you exceed the optimum density for maximum empower production. You will get less total production by doing that. By keeping your water distributed in natural hierarchy, which is what nature does, keeping

it spread out, then you get more. Counting what you can buy and bring in, you will get more development if you are interested in development. You will get more economic development by developing both areas than you will by trying to let one area that is already fully developed to overdevelop.

B: Even accounting for the 15 million people they expect to live there, that would still hold true.

O: No, those people would be further north and those people will have a better chance to survive when the fossil fuels collapse.

B: Have we talked about Florida Bay yet?

O: No.

B: Okay, let us talk about that.

O: Florida Bay is naturally like the bays of Texas that I used to work in, that is, it is a little bit hyper-saline. Sea water is three and a half percent, thirty-five parts of salt per thousand, but Florida Bay salinity is higher. When the salinity is high, as we have already said, it tends to channel the productivity into a few things, so they traditionally had a lot of pink shrimp, for example. When the Everglades waters were diverted, there was more variation there, upsetting ecosystems. A persisting impact is the turbidity from dredgings. Sediment is loose, it takes a long time for it to get pinned down by plants and microbes. Every time the wind blows, or boats pass, it stirs up. That cuts out the light, cuts out the productivity. Around the Keys, within a foot or two of the surface, are magnificent grass flats and other animal consumers, wherever it is shallow enough. As soon as you get deeper than that, the ecosystem is less because the light is shaded out.

B: And what will be the impact of that ultimately?

O: Well, right now you have less productivity and less wealth. Management can do some things about that, eliminating dredgng. Partly it is boats with too much power. Getting the Everglades water flowing back through there will probably help the Ten Thousand Islands.

B: How about the issue of the freeze line moving south and the transfer of the citrus south?

O: As you know, the orange industry in Florida used to be more in central Florida, between here and Orlando, and then very severe freezes knocked most of the trees out, so growers moved south and drained wetlands there instead. The amount has not been calculated, but I think that the freeze line has moved south because of the draining of the wetlands in north Florida. It has been proven that you keep oranges protected best with water rather than with smoke or air turbulence.

B: How far south might it be lost?

O: You know, the orange industry now is from Orlando south.

B: How about the Fenholloway River, did you work on it?

O: About 1953 I was here as a young faculty member in biology and teaching limnology. A proposal was made in the legislature to classify the rivers of Florida, not according to their values, what is in them or in the ecology, but according to the uses we wished to make of them. The classification included a category for fresh water drinking and one for industrial waste.

B: So this was when you were first at Florida in the 1950s.

O: Yes, that is right. Here is a young guy right out of school, and they took me up to one of the legislative committees in Tallahassee and I tried to explain environmental value, but it did not have any effect. Although biologists were against it, they went ahead anyway and made it an industrial river. So they set up the paper mills at Perry and dumped black wastewaters into the river, including the toxins, etc. One-third of the tree is lignin, and when the tree decomposes, that lignin which is natural, normal, becomes the peat or the peaty-colloidal black waters, and they are healthy. Lignin is one of the best absorbers of toxins and heavy metals. Consistent with the Gaia idea, wetlands have developed as trees developed lignin, so that the whole system will continuously purify the freshwaters of the earth. Should we burn peat, or use it for water purification? In pulp-paper manufacture, we take out the fibers, leaving a third of the weight that goes into this black water that we dump somewhere. Lignin itself is not toxic, but in huge concentrations and with the wrong molecular size, it can use up the oxygen too fast and knock out ecosystems. So this goes down the Fenholloway River. As documented by Skip Livingston, much of the life in the Fenholloway River estuary and coastal waters was displaced. The grass flats that you find north and south of the mouth are missing in this zone. A whole section of tourism, fishing, and environmental attraction was removed. We had a thesis done by Peter Keller to help bring out a better idea, which is that lignin ought to go back where it came from, which is into the pine-land wetlands. There it mixes with the ordinary lignin and becomes part of the gradual purification. Having some black water in the streams is fine. That is what colors

the Suwannee River and to some extent all rivers. When government agencies finally decided they were not going to allow this discharge, about three or four years ago, the company proposed a pipeline.

B: Into the Gulf.

O: It would get it there quicker, but with less treatment. And so then, Steve Medina, who is a lawyer, representing a local group, got some of us involved in evaluations and alternatives. We have two plans. One was to pump it uphill, back into the pine-lands and into the little swamps that are between the pines. We calculated all the energies involved and what it would take, and all the emergy. Mark Brown's idea was to build a strand, that is, a strip of wetlands, and run wastewater from Perry into the coastal wetlands and into the marshes. By the time it went through there, all the lignin would be absorbed or mixed with the natural lignin and would gradually be an ordinary black water. The industry would remove toxins first. Both of those plans turn out to give the area a multimillion dollar benefit in emdollars compared to the river or pipeline discharge.

B: What was the response to those plans?

O: They had us come in and testify at hearings. I guess they had trouble with me because my testimony was to help keep industry jobs and environmental values. If you do not protect environment there, the pressure of tourist interests and retirees is going to build up and drive out the pulp mill, and so that does not make any sense. Increasingly the shortage up there is water, and pulp-paper mills use much groundwater. If you put it back in the pine-lands, it percolates and recharges the groundwater. The only problem is you have to get hold of the lands or get easements so you can do it.

After that, the EPA government agencies took it under advisement, and I guess the whole thing is still pending. That is one of our current controversies. Bob Knight's studies showed wetland treatment of pulp mill wastes in the panhandle of Florida. It is not just at Perry. I went over to the St. John's Water Management District at Palatka and gave a lecture there as well, on the study we had made--Peter Keller's thesis that he did. . They brought in the people from the pulp mill there. For a while they had run some of their waste into their floodplain wetlands over there, then the EPA forced them to dump it into the river instead, which was stupid. Peter Keller's thesis on that wetland showed that the tree growth had increased during that period, and the diversity had been maintained. In other words, wetland dispersal was a good solution they had before, and they needed to go back to it, after they remove the actual toxins. I hope we have been making progress. But that has been our role, finding the correct answers with good ecological engineering. With new ideas and evaluations you still have to wait until the pressure for change builds up with a clientele to get political action. That is where the journalists could help, if they would just take some time and learn about emergy emdollars, and insist that an emergy evaluation be made of everything. They could cause the environment and economy to improve greatly.

B: How did the Buckeye Cellulose pulp plant respond to that proposal on the Fenholloway that you guys had? Do you remember?

O: I don't know. Actions are still pending. We are going to write all this up one of these days, but I was going to wait until there was some kind of a solution first. Of course, industry often thinks short

range, what do we have to do this year, or in the next three years? They keep buying and selling that plant.

B: How have citizen activists generally responded to your emergy analysis?

O: If we get a chance to explain it, they like it unless it goes against something that is really deeply ingrained. Example, controversy on a fish pass for the Rodman Dam with Marjorie Carr, after Archie Carr's (herpetologist, University of Florida, 1933-1987) death. She was an activist. I studied Silver Springs several times. When the Rodman Dam cut off the mullet, the shad, and the big catfish, Silver Springs had less to show their tourists. I had another thesis done on it by Bob Knight, who is now an authority on ecological engineering of wetlands.

[End of side 2, Tape B]

B: This is side 1 of Tape C.
Continue, you were talking about Silver Springs.

O: Silver Springs was losing some of its natural attraction because of the Rodman Dam. I prepared a letter to the editor. A fish pass was needed. I had already written to the Silver Springs management to get them in back of it. I mentioned it to Marjorie Carr, and she got upset and asked me not to write it. The dam is only about twelve feet high, and it would be no problem running a very shallow ditch around it full of aquatic plants, perhaps a mile long, and get all the migratory fish back. She was afraid a fish pass would be an excuse for them not to remove the dam, which she believed would happen

soon. I should not have listened to her. That was ten years ago, and here we are, with a dam and no pass. So I think I should go ahead and write it. That is an example of the kind of unbalanced environmental activism that I think is wrong. You ought to have all the facts out there, public. Then we can put them in perspective using the emergy method. But you can see that some activists do not like us because of that policy.

B: Let us go back to the point about the students. You mentioned the environmental agencies, both at the state level and the federal level, being filled with perhaps too many conservation-minded people. Let us follow up on that point.

O: You misrepresent me. I am conservation-minded, it is what you mean by conservation. As you know, it has a bunch of meanings. It is policy against new ecosystems that I oppose.

B: I want to talk about who peoples those agencies.

O: I don't know many agency people, but I can discuss public actions and policies.

B: But at the same time, at least in Florida, it seems that many of your students have gone on in important positions in the state government, and local governments, and water management districts.

O: They have to compromise. They end up with some kind of a blend. It is interesting. I guess there are a hundred of them out there that have come out of our programs in the last thirty years.

B: Do you end up talking to those students later about those compromises?

O: Sometimes, once in a while. But I have dropped the ball too many times by being slow to reply. That is one of my regrets. Another regret is that the Center for Wetlands has yet to be endowed. It has done so many important things for the state and has more potential ahead. It needs a big permanent endowment, and I should have gone out after it. We were busy with the battle of energy policy and publication needs. The Center for Wetlands was set up under four colleges with an inter-college board. Engineering was one, IFAS was another, Planning and Architecture was another, and Arts and Sciences. When I was on sabbaticals, we had acting directors from those other colleges. Endowment for wetlands should have been part of the University of Florida's priority list, which in recent years campaigns for private money. Dean Wayne Chen gave Wetlands a hard money secretarial line item. But John Lombardi (president, University of Florida, 1990-1999) dismantled the cross-campus centers and turned wetlands over to engineering. I decided not to fight that, although it was against the Board of Regents' authorization. Engineering was happy to have it, but it was not one of their priorities. They would not put it in the priority for the money seeking. Nor did the main administration. Each college had other priorities. So, no endowment money was sought. Multimillion dollar grants may yet be possible. It was hard to campaign for money and maintain a graduate program of critical mass, but I could have done more.

B: Yes, I supposed in the Engineering College, you would have computer and aerospace and other industries contributing huge amounts of

research grant funding. It must be hard to compete for attention against those departments.

O: No, the Center for Wetlands has received good research project monies, good support from Florida Phosphate and from the National Science Foundation--all kinds of places. It operated at around a half-million dollars most of the time it has been existence. Engineering emphasizes technology design, but engineering needs to include environmental design also. They were happy to have the center, but they were not going to push it. When I retired and Ronnie Best left, only one was replaced. We now have the means and methods for proper use of wetlands, how to evaluate them, where to place them, and how to deal with nutrients. Most of the kinds of wetlands have been studied. Both wetlands and ecological engineering now have graduate certificate teaching curricula. The environment still remains second priority in public affairs in Florida.

B: I guess particularly with the technology explosion that is going on.

O: That is right. That is why coming back to a lower energy world is going to be a challenge for university research. People got the idea that technology was energy free, and I think the current economic turn down is correcting that idea. The more information is processed, the more high-tech you have, the more energy it takes to service, just to operate the internet or its servers in other states. Progress, technology, information, is energy-driven and so is the economy. The minute your energy supply tightens up, then your economy levels, and information growth stops. Then, when it gets even tighter, you have to cut back. It does not mean you stop all progress, but you reduce innovations. Descent is coming, that is

why we need to get task forces started to study and plan. It is political suicide probably, for anybody, even a well-established politician, to come out and say that growth is over. To hold the standard of living, we have to cut back and reduce population. It will be hard for religious leaders to change. Otherwise, population will be reduced by epidemic diseases and a crash. An economy that does cut back takes over economically. All of that reverses our growth culture. Growth is in our culture, and worse than that, it is in the Constitution. The Constitution was written for an expanding colonial, invasive culture moving into a new continent. You are going to need constitutional amendments. Even the very fundamentals of private property, mining rights, and western water law, and things like that which are designed to accelerate growth have to change.

B: Let me throw out just a couple more big-picture issues and Florida issues, such as the destruction of citrus trees and pine trees to stop epidemics like citrus canker and the pine beetle.

O: Nature maintains stable production by not having too many of any one species. Rainforest that we have studied so long is an example. An area of rainforest has a hundred green tree species, but each one is chemically different. For an insect to eat it, it has to have the different enzymes. An insect that can eat one does not have energy left to maintain enzymes to eat another one. The next edible tree is over yonder somewhere and the insect cannot get there without a bird eating it. The birds are set up to eat many more kinds of insects. So diversity is the way you prevent epidemics. On the other hand, some pulsing is appropriate. Those are two principles there.

Now when we do agriculture, intensive agriculture or intensive forestry, we build monocultures. That is only possible because we set up some way to defeat the consumers, the insects and microbes that would normally run rampant, consuming and destroying. We use pesticides on the one hand, or we develop more sophisticated biological controls such as insects that control other insects.

The question is, should one special interest set up a monoculture that disturbs the environment that is adapted to human settlements? Many Americans live in stable landscapes that have some pulsings, some tree growth, and some diversity, adequately managed waters and economic prosperity. It is a pleasant, diverse environment for people, particularly in an urban society. If somebody sets up a plantation monoculture, and all of a sudden is having trouble with pine beetles, citrus diseases or fruit flies, do they have the right to go and destroy the landscape and its nice balance just to favor their enterprise? Cutting trees that are not infected makes no sense when they are scattered in housing areas where tree diversity is large. Again, whenever you have to chose an alternative, you should do an emergy evaluation. Where a landscape has nothing but those plantation trees and nobody living there, the emergy analysis might favor removal of infested trees. On the other hand, in modern Florida with its high diversity, with most people doing something else besides raising monocultures, that does not maximize emergy and emdollars. The emergy of the residential areas are greater than that of the crops.

B: But agriculture is still the number-two top industry in the state.

O: That has been the justification, but there are other ways to be productive too. You do not have to have an agricultural monoculture, you can have four crop species instead of one, and more genetic varieties of the same crop.

B: Has anyone done an emergy analysis that looked at the citrus canker epidemic?

O: I do not think so. Someone should do it. [Interruption in tape.]

In our yard we had one pine tree get full of insects and die about twenty years ago. So what? It decomposed, and it had woodpeckers in it for awhile first. On our one acre lot we have maximized diversity, which probably keeps any local infestation from harming somebody else. Our other pines were not affected. Of course, I am happy to follow any regulations, even if misguided; with diversity one tree is not that important.

Another big mistake is planting ornamental monocultures. For example, putting all the elms along all the roads in New England was a big mistake that led to an epidemic of Dutch elm disease. Maintain the diversity within a plot and also maintain the diversity of plots. Agribusiness tried to increase global food production with miracle rice. My first energy evaluation was on this in 1966. I was in North Carolina, and they invited me to go to Washington as part of the President's Science Advisory Council, which was taking up the question of energy and agriculture. We brought our evaluations showing the energy basis, and boy, the agriculturists landed on me like crazy, and the subcommittee voted twenty-to-one not to include my section, which had calculations of what was wrong with their miracle rice. But the main committee said, "those guys

are biased and narrow," and included my report. It was our first publication on what is now called emergy evaluation. That report on agriculture was from the White House and shook everybody's view of agricultural progress.

B: Could you follow up on that idea a little bit? If we should not have monoculture in Florida, who should do it?

O: No one. Maintain genetic diversity in agriculture. The latest problem is monoculture within the same species. Molecular biology produces new insect resistant varieties of corn. The next thing you know, Monsanto or somebody has got all the corn in America with one genetic variety. That means it is set up for one disease mutation to cause national famine. There are other worries too; if it is toxic to insects, how toxic is it to your unborn child? I used to study experimental embryology at Woods Hole. We used to add little tiny bits of chemicals like lithium to Arbacia (sea urchin) eggs and watch the normal growth go twisted and produce abnormal embryos. This business of changing the chemistry of food is awfully dangerous. The people doing it, molecular biologists, have less and less knowledge of systems or complexity or the next largest scale (ecology and environment), or even of economics. They are dedicated and push for this and it sounds great to people who don't believe there are limits. The public has a feeling that something might not be right, but it may be worse than they realize.

B: How about the frenzy over mosquito-borne diseases?

O: Well, when we set up our big project (Rockefeller-NSF) on wastewaters in wetlands, we brought in a Public Health virologist with a chip on her shoulder, determined to prove that

environmental recycling was dangerous. We set up sentinel chickens all around to monitor misquito bourne virus. We also took samples for other viruses in the waters, and then down underneath the swamp waters that percolated down through the peat. These wetlands act as a very slow filter and recharge the groundwaters. They also flow laterally. She hunted, hunted, hunted, and finally found one virus underneath all her measurements. She said "even if it was only one virus, if it had been the St. Louis variety I would have tried to shut you down." St. Louis is the encephalitis that has had epidemic-like properties in Florida cities. It is transmitted by mosquitoes, not natural mosquitoes, but the exotic mosquitoes that come about when you have temporary pools in towns. What killed the people in the yellow fever epidemic in the Panama Canal development was not the natural mosquitoes. It was the African Aedes aegypti, which had been brought over and grew in flower pots. That brings me around to the main point, that if you rush in and spray, and they are doing it right now, you knock out the natural insect fauna and the checks and balances with the hundreds of insect species that eat each other and so on. Spraying may make the mosquito problem worse, with a few species which are capable of creating an epidemic. Chemical spraying is absolutely wrong, this knee-jerk action, but the public does not understand. Anyway, in our studies, I put sentinel chickens out in back of my house next to the pond, and there were not any viruses there. But Eastern Equine Encephalitis (a bird virus that rarely affects humans) was discovered in our wetlands. So we quit having students stay overnight out there. Gabriel Bitton joined the department, and did viral studies.

He set up columns of wetland peat for percolation, and showed that water viruses don't last long before being denatured or eaten by something. So anyway, our experiment to put treated sewage waste waters in wetlands had worked out, and is now practiced worldwide. Early on, somebody in that area said, "just wait; if that filtration doesn't work I am going to sue that guy (H.T. Odum)." To do something new, you have to be a little tough and grit your teeth.

In the trailer park that supplied the wastewaters there was a darkroom that was releasing soluble silver into our wetland, which it sucked up just fine. Later on, we got an EPA grant to set up barrier strips in the swamps at Waldo in order to flow waters with heavy metals over the peaty surface. Heavy metals did not even get thirty feet before they were absorbed. People have worried that wetlands would later release substances that they absorb. With the Sendzimir Grant we set up a project with Poland where they have wetlands that have received mining wastes for 400 years. They were doing just fine after 400 years. We have just published our book with CRC Press on heavy metals in wetlands. It summarizes our ten-year project. It is full of emergy evaluations as well.

B: This is Heavy Metals in the Environment: Using Wetlands for Their Removal.

O: That is not the real title we started out with here. It was a multi-authored report with a technical name, but publishers change your titles to sell more copies. The cover made it look like it was only my research, whereas it was research by ten authors. A main part was from Joe Delfino (Professor of Environmental Engineering Sciences, University of Florida 1982-present) and his students.

B: What about the mercury showing up in all the fish and panthers in the Everglades?

O: Professor Delfino has been a major researcher on that one. In addition to the natural cycle, incinerators release mercury into the air that spreads over and rains down where it absorbed by peat. Later, when you drain the Everglades, it oxidizes and mercury is released again. Mercury tends to go to the top of the food chain, even in the sea where it concentrates in swordfish.

B: I was gong to turn to some sort of big-picture Florida questions. What do you think is the worst environmental mistake we have made as a state? That is a hard one.

O: When you say environment, I do not separate out the environment from the economy, I put the two together. The worst mistake in modern civilization is allowing excess automobile horsepower, allowing unnecessary cars as part of our freedom, allowing individuals to apply power to things that do not reinforce productivity. That is, we run cars and build throughways instead of asking what is the most appropriate transportation to make an optimal fit of people and environment. But in a free society with expanding energy, maximizing power allowed each individual using an individual car to save a couple hours a day, and time is emergy. Soon that is going to change drastically. Recall the energy crisis that started in 1973, which by 1980 created huge inflation. We are about to do it again with new energy changes. There is little institutional memory of this anywhere in government. Only senior people in universities understand the things what were discovered and worked out, that we call net emergy evaluations, the

government people are all gone. We have got to turn to the previous knowledge or else repeat the mistakes. The governors of Florida have all been developers, by and large, and their maximizing population growth was certainly a mistake. You have to maximize empower, that is, you have to maximize your total use of energy, but maximizing the population, when you are going to have to cut back, is very short-sighted. There has been a whole bunch of mistakes connected to the energy problem, such as encouraging air conditioning to displace windows.

B: What are some of those lessons from the 1970s and policies that are not being followed?

O: An example is, agriculturalists would like to think that they can substitute corn for oil by making ethanol. Ethanol can be used, as in Brazil, but our emergy evaluations agree with those of others that there is no net contribution. Somewhat comparable methods all show that by the time you have taken the corn and converted it into alcohol, you use as much fuel energy as you make. The only people who claim net yield leave out the emergy in the services. They say there are not many calories in human services, and we will leave them out. Of course, what goes into the raising, and paying, and supporting of all those people is huge, so we include it and they do not. Five or ten years ago, a public hearing was held locally to promote ethanol. They had one of the congressmen, the IFAS people, and somebody invited me, along with nice news people. Everyone made little speeches about agricultural ethanol as a new industry for Florida. I got up and pointed out that there is not any net gain when fossil fuels give you around six times more yield than

is used to process it. Ethanol gives you about 1.1 more than you use, so it is never going to compete, it is not a good benefit, and therefore it will not be economically competitive as long as there are fossil fuels. Of course, they were embarrassed. The new company they had just formed went bankrupt about three months later. We have had this running war with well meaning people wanting to do things that are not net benefits because they are not quantified on the right scale.

B: That reminds me to go back to fossil fuel, to petroleum, for a moment. We were talking about the eastern Gulf of Mexico earlier, and you were saying that there was not as much petroleum there as there is in the western Gulf.

O: Sediments from rivers were deposited west of a north-south line through Tallahassee.

B: What I wanted to ask you, should we be drilling around the Apalachicola embankment, where we know there is a lot of natural gas? Is it appropriate Florida policy to just let them go ahead and drill that?

O: All these emergy evaluations have to be done at several scales. You could look at the scale of the company that is going to do it, and whether it is a net benefit to them. Then you can look at Florida, and then you can look at the nation. For Florida, the emergy involved in that amount of fuel could be evaluated relative to other things going on that would be hurt by it. Pubic opinion senses net harm if you start to get oil spills all up and down the coast around Cedar Key and Clearwater. You probably would not have a hard time just proving that with emergy. On the other hand, "energy will out,"

as we sometimes say. However, a country like the U.S., that is trying to have world influence, is in position to do things worldwide, expected to, and it is our public policy to, had better save something for an emergency. That applies to Alaska and its north shore. If you could do the exploration and not develop it--that is a hard thing to do. National policy ought to save home reserves and use foreign fuel first.

B: Once they find it, they want it.

O: Not only that, but the money is needed to keep oil drilling companies alive. They have to operate with capitalistic investment. On the other hand, government could authorize the exploration but not the development of it.

B: This is an interesting idea.

O: Because of our fuel waste, there may come a time when the U.S., for lack of net emergy, loses its place as a leading nation. We are not as close to the Near East and central Asia, and we may be in serious trouble soon for lack of reserves. Of course, we have several times tried to reinject oil into underground reservoirs. We are doing it now. But the first time the price rises, they go and pump it out again. The Teapot Dome scandal occurred during President Warren G. Harding's administration and involved the leasing of naval oil reserves to private companies. It was an original reserve that was saved for emergency and they went ahead and used it. It is pretty hard not to use available energy.

B: What do you think Florida has gotten right in terms of environmental policy?

O: I think it is ahead of the rest of the country in getting people concerned, developing environmental groups, and the water management districts. Florida has many kinds of environmental organizations, and a lot of laws.

B: Do you think our efforts to have growth management laws have meant very much?

O: You know, environmental support has been on and off. The alternation between free growth and management can be compared with stages of an ecosystem. Free competition takes over when resources support fast growth, whereas organized control and efficiency comes when growth stops. But in human affairs there is a lag in public opinion. As growth slows, many want to go back to growth time with dog-eat-dog competition, and the government has a minor influence. The minute things start to level off, people say, "oh my goodness, growth just stopped, let us go back to being more independent, let's get rid of government," when actually the need is just the opposite, you need your government regulations even more, because that is when you have to make things efficient, and not destroy one thing to fit another.

B: Who are the Floridians you think have been particularly good stewards on behalf of the environment?

O: Of course, Askew was pretty good, Nat Reed, Earl Starnes, and John DeGrove helped. In recent years Graham has done some, even if he can't or won't discuss the long range. Faculty in the universities have provided ideas and results of research.

B: So you wanted to put up a barricade at the Florida state line?

O: No, no, I never advocated that. The economy has to follow the maximum power principle. I seek a task force to look ahead at the time when everybody will be forced to do less. Fewer tourists will come. The second homes will be put up for sale, and few will afford air conditioning as electric power becomes so expensive. Priority for electricity will be for information, TV, and internet. Retirees will not be able to sell homes for profit and come down, some will arrive broke. Hopefully delayed marriages and more women at work will reduce reproduction. We know about these trends because every time there has been a small turndown, we observe them. When you have a major turndown, states like Oregon with hydro-power have an advantage. But in Florida we do not have to crash, nuclear power plants are likely to be replaced, for another cycle of uranium fuel is still available. Why can't we get a task force going? Part of the problem is in the universities--there is so much pressure for the young faculty to go out and get money that they go to industry and agencies for money that is not related to the long-range future. Industry does not look way ahead, nor does government. The only people that can do long range studies are universities, and we are paid to do it, and that is what we ought to be doing. Society needs to stop this pressure from the deans and chairmen. It is terrible pressure. You need to tell the young faculty members not to seek grants for three years until they develop some new approaches. Universities are not doing their long-range job.

B: Let us talk more about your long-range fears about what could happen here.

O: You call it fears (a cultural negative attitude to descent), and I talk about it as the prosperous way down, not a fear. The fear is that people will not recognize it in time to bring to bear the public opinion on their leaders to do sensible things, and that is what we're in, the business of trying to shake people up. The more we shake them up, the more that we think they are nuts.

B: What do you mean by the Prosperous Way Down? This is the title of your recent book.

O: There are lots and lots of policies in there which would allow the total economy to come down without loss of living standard, providing the energy consumption and the total buying power come down at the same rate that you get your population down. The real wealth per person (standard of living) stays the same. Then you can hang on to your medical care, prevent epidemics, and depressions, which can cause a society to disorganize. You can do away with unearned income, for example. Americans have suddenly, just in the last ten years I think, have the idea that unearned income is OK. Unearned income is interest that you get for doing nothing. The idea that it is a god-given right was involved in the last election. The idea of taking your savings or Social Security and making more money out of it only works during growth. I remember the consequences of no growth--how it was in the 1930s when we had a period of the Great Depression. Borrowing was regarded as evil, dangerous, and only for low interest. The culture changed. You learned to adapt to what is, and enjoy small-scale things. Our current generation, maybe your generation and younger, need to understand about the fossil fuel pulse of our economy and that it is

unsustainable now in its final glorious pulse of information. After a time, environment restores some reserves and another growth pulse can occur. But the present pulse based on fossil fuel is much higher and stronger than later pulses will be for a while because we will have to go back to basing our rhythms on fisheries, forests, and agriculture.

B: What do you think the time frame is?

O: There are a set of new books out by the resource geologists, not from government, predicting climax before 2010. I, of course, put a lot of this in our new book. Publishers also had us include a chapter on the state of things now. We were lucky to get the book published at all with this title. Lots of publishers turned it down. They hid our diagrams by making them too small. This makes it hard for the reader to understand. Perhaps they thought it could be read without them.

B: The peak is 2009.

O: Yes, but the long range trend is hidden by pulses that have to do with OPEC (Organization of Petroleum Exporting Countries), wars, and short economic cycles, so you cannot extrapolate to find the future. The present economy slowdown--people think that's just an economic oscillation. They just do not get it that the economy depends on the available real wealth being used. When the price of fuel goes up, that means that less fuel is going into the economy than before, and therefore, growth cuts back. Our leaders and their advisers don't realize that the economy is based on real wealth, and real wealth is based on this fuel and matching renewable resources like water. We tried to put that into the elementary courses, our

way, teaching as a system; it really does work. We do it with these little systems diagrams that include money. I am not sure you can explain it adequately without them. Energy systems are used a lot around here and around the world, but many people turn off when they see networks. It is not generally adopted, and most people don't understand their economy and its future. Not until they get a future shock will they take time to learn, so that is where we are.

B: So what would you propose that task force could do? Would this be a Florida task force?

O: I think we need it at each scale, each division of the government needs to have at least some small percent of their budget going into planning for a lower energy future. Make it clear that we are not advocating descent, but getting ready for it. We are saying that when you are going to be forced to do less, what is it that we are going to do that will retain our quality of life, standard of living, health, and some progress? Conversely, what will wreck us? Just cutting the horsepower of American cars back to where it was five or ten years ago, more like Europe, would keep energy waste from limiting the economy needs for some time, but eventually, it has to come down more.

B: Unfortunately, people would not get elected on that platform, would they?

O: Not until the public sees it, then they will all jump on the bandwagon and say, "I told you this years ago," and all that. This pulsing phenomenon must be obvious to you as a historian, this business of building up to a crescendo of stored attitude followed by a public reaction. The time between pulses depends on the turnover time of

the accumulated feelings. The easiest way to put causes and plans on the same basis is emergy (that is energy of one kind). Then we can straighten out our understanding of history also. We have had several emergy evaluations of historical events interacting with historians.

B: Emergy in history?

O: One is Bob Woith's Ph.D. dissertation on emergy evaluation of the Civil War. Michael Gannon was on his committee. Another was our joint emergy paper with a Swedish historian and forester on the wood, water power and silver basis of their empire of the 17th century (the reprint that I gave you). The historian added a minority report, saying this emergy was not going to be very important, although he said he enjoyed the exercise. Historians want to believe that great people can make a difference. Well, they can, if the transformity of their influence is high enough. Do they think there are any common principles beyond that? Do they look for explanations in networks of energy, water or other sources?

B: I think that is really changing. The history discipline seems to have embraced more of an ecological viewpoint, starting in the 1960s, when the other parts of the country were becoming more aware of systems and the environment, so it does seem to be changing. I think you said earlier you had more optimism for the environmental future than for the human future. I know I am not paraphrasing you exactly right.

O: My optimism is for the environment with an adapted, lower energy human culture--held together by global information sharing. I do not think we have enough fuel to burn ourselves off the planet. We

are going to run short before we wreck the biosphere, and limits are appearing now. Is that optimistic?

B: Before I met you I was curious whether you were an optimist or a pessimist, and it seems that you are an optimist for the environment, but perhaps a pessimist for humans.

O: You show your pessimism like most Americans when you automatically equate descent as bad. Within thirty years you and the majority will have switched and will regard growth as bad. Betty, my wife, in the later chapters where we talk about what it means for individuals, tries to make it a little more vivid than in my writing. Life is much better on a smaller scale; it is bicycles and friends and neighbors and more care, and not such a frantic time; and more of a village taking care of the children. There have to be fewer children, but you can take care of them better.

B: I can see that.

O: The assumption that coming down is pessimistic is in our culture, that is the first thing I have to hit on the head. Coming down can be prosperous if you do it right.

B: It seems like it would be difficult to be optimistic when you have seen some of the environmental destruction that you have seen, whether it be here in Florida or in the Amazon rainforest, you have seen some of the worst of the worst.

[End of side 1, Tape C]

B: This is side 2 of Tape C.

You were just saying how you have seen how nature fights back, so to speak, how it recovers.

O: Often it uses exotics to repair. Also, I think society adapts. Self-organization with ecosystems will do it beautifully. However, if you look at history, there are some societies that came down crashing. You have many examples. I will ask you to identify some cultures where they came down gradually, more prosperously, shall we say. Perhaps Japan is ahead of us in adapting to no-growth now. Many ecosystems grow and descend seasonally every year. I just was in Alaska, with summer growth everywhere. Then some hibernate, some put out seeds, and some migrate. Life turns down, and then turns up again--the whole rhythm is prosperous. The reason we have a problem is our small scale of view, and we have not been through this exceptional growth high peak. We do not have any precedent or any cultural memory. We have the history of Roman descent, but people of our culture think of that as failure, a million theories of course, whether it is lead in their blood, barbarians, or the brilliance of organization spreading to other cultures so they no longer had a monopoly. I do not know what your favorite combination is. I only read one volume of Toynbee. I think it is inherent in the maximum power principle that you alternate with pulses up and down. We use the analogy of flashing lights on a Christmas tree. While one center of activity flashes, another is between pulses That is also our theory of the universe, instead of one big bang, we see the universe as a bunch of pulses. On the larger scale that gives you a steady state.

B: When you look around today at some trends such as urban infill and this proclaimed desire to return to the old types of walkable city, do you see that as positive, as a good sign, a potential solution, or do you think that is just another way of developing Florida in a new way?

O: As you know, there is a struggle between the infillers and others. I may write a letter to the editor on that if I could get them to publish one of our hierarchy diagrams (refers to picture). The natural hierarchy of energy is the key thing, and it is in the revision to my 1971 book that we are trying to get published now. It is the second edition of Environment, Power, and Society. This time it's called Environment, Power, and Society and the Hierarchy of Energy. That hierarchy is this thing that we just talked about, different scales, each connected to the next. Pulsing occurs at each scale. The bigger the scale, the bigger the pulses. There is also this spatial organization. We believe it looks like this (refers to diagram): little centers converge to bigger centers, bigger centers to even bigger centers, and so on. The concentration of annual emergy use increases to the center. The successful development maximizes the economy. It is neither solid infill nor green space predominating. Doxiadis showed the territory of a person's travel increases according to their role in the hierarchy. Those in centers have larger territories. If you fill in solid, you knock out the basic matching of developments and environment (see figure). Centers that are organized in appropriate density in relation to other centers and connected up appropriately with converging pathways, roads, and bikeways are correct. Sometimes developers may get closer to

the correct distribution, not solid bands building out. So I think there are principles here that explain the right development that will be found eventually, but you may make some mistakes along the way. That is what humans do, they either do it right to start with or they do it wrong and have to correct it.

B: Is it Eugene, Oregon, that has a very dense urban center and has created a boundary around, so there is not any development in the rural areas outside?

O: Our spatial work has been done in collaboration with planner Shu-Li Huang in Taipei, Taiwan. He spent two years here, and we have been out there several times. They have an agricultural belt that they have kept, a little like the London greenbelt, except theirs had a defense purpose. They wanted to hang on to their agriculture in case they had to support themselves in their struggle with mainland China. Such things from the large scale warp the self-organization a little. Even so, his patterns of Taipei fit the pattern of emergy distribution.

B: Are you saying that neither the urban density nor the suburban sprawl is the appropriate pattern, that there is something in between?

O: Yes, there is one in between that fits the natural hierarchy, and we know what the emergy ratios are because it is the amount of energy at one level to make the next, and it has a spatial pattern that maximizes the combined economy of people and environment. Again, people have to follow principles, even if they are foreign to everybody's thinking and have to be found by trial and error.

B: I wanted to ask you about your personal level of emergy or energy because you have been so prolific in publishing papers and books. I think you have 90 masters and doctoral dissertations and more than 85 grants. I just wanted to ask you where your personal level was?

O: Maybe I took on too much, because some of the best results are still in unpublished reports and theses. We could have taken the time to influence the public more. At mid-century publication would be enough for people to find it and be influenced. Now, however, we drown in information and few scholars read beyond their immediate needs. And more results need to be published in journals. That is what I am now doing, since I got sick in 1996 (ok now). We have also put out five books these last two years.

B: Where does all this personal energy you have come from?

O: My brother says that we are driven, whatever that means. My fundamental ethic is that people should make a contribution to the larger system. They are probably in a better position to decide what that is than anybody else, so that is a form of democracy right? Your priority should be to make some contribution to something. For kids, their contribution is to learn, after that they find something they could do that they feel is contributing. Of course, after I stumbled onto some of these fundamental principles, I knew it was important. After we locked horns with everybody in traditional energetics, it has been like a war ever since to try to get these things proven and demonstrated. We know that people are not going to switch from what they learned until everyone does, when the switch is forced on people. You realize that you have the key (energy hierarchy concepts) to understand the earth and the

universe as well, and that it is a more general way of looking at it than any of the other theories for explaining things, so why would you not do the best you can to get it out and into society's long term memory?

B: It must be nice to feel you have the key to the universe.

O: People call that arrogance, and once they hear that they do not read any more. So we try various ways to explain concepts. Even our students have to go with the majority to keep their jobs. So they have mixed feelings about their former professor. Collaborating with my wife has helped me to write for community college level.

B: That is one of the values in your collaboration.

O: Yes. It is humility, too. If you have a million educated people who believe one way, then you have got to be a little bit strong to keep pushing, right? For example, energy theories of value were pushed, back in the 1840s when energy was historically invented by scholars in three fields. They invented it, an energy concept different from the public idea, which is more like emergy. Since then, many have been trying to get an energy theory of value. The book by Martinez-Alier reviews all that and shows how many times it was offered and how many times it failed and was rejected. People were discouraged. The reason is, they were erroneously adding energies of different kinds as if their work was equal. Once we got that principle right, which is this hierarchy thing, then we realized that emergy measures natural value--real wealth. That is why it is a breakthrough, but it is not the kind that people want to recognize because it is a paradigm switch reversing a premise of most of the scientists. Eventually somebody will catch global attention long

enough for everyone to catch on. Reorganizing descent is another paradigm shift which will not happen until everybody in the entire world gets up to that point where they say we have got to cut back, and energy determines our life after all, and then of course some will say we knew it all the time.

B: One thing that I think I am still not clear on is the human management of systems. It is hard for me to grasp whether we should be doing this management or whether we are just part of this larger system. Do you know what I mean? I did not ask that question right.

O: The earth system uses the emergy that it has accumulated in the human society's amazing information capabilities and social coherence to better organize the planet for maximum empower and information memory. The earth used to do the best it could with inherited and genetic evolution which was slow, there were pulses of progress, but now all of a sudden evolution provided humans with this special ability of being able to process information better, not only individually but together as a group. Thus, the earth has an entirely new breakthrough. Of course, one of the great speculations is where else in the universe is there such information processing? It is very high in transformity, to use our word (emergy per unit). Even when humans are doing things by trial and error, it is fast and better than if you had selection of genetic alternatives by trial and error, taking a million years to stumble into the right one. With trial and error and excess energy humans developed computers in just 50 years. That is fantastic progress, right?

B: But we are not doing better if we are destroying ecosystems like the Everglades and are unable to fix them.

O: Well, we are fixing them finally. They had to get worse before it could get better, right? They are following some of the things that we reasoned. The final point to your question is that we are beginning to understand enough to where the humans can do management according to what is logical sometimes, rather than letting trial and error tell us what works. We are not quite there, and the public does not even believe it is possible, that some things are logical. It is just incredible, in my lifetime, the global sharing of information that has happened. For example, when I went to meteorology school back in the 1940s, nobody knew anything about weather at all, and now everybody has global understanding from the weather channel. The money programs have diverted people away from the ideal of contributing. That was all right for the growth period, but now from somewhere we need a person who will explain the principles to lead the way down. Various politicians might, but they have no time to listen.

B: It seems like Gore would have been open-minded to that with his book Earth in the Balance.

O: We might try again. We bought copies of The Prosperous Way down to give out, but don't have a lot of money. Perhaps we can get the book reviewed in enough places so that it comes to public attention. Even if journalists want to tease and make fun of it, it might get more people thinking. I think it is already in the subconscious of half our population that we are coming to some new state. They are

trying to say our civilization is sustainable, that it will level off, but it is not sustainable.

B: Just back to human management for one moment. I wanted to ask you how the current focus on cloning and genetic engineering and so forth fits into that. It sounds like you do think we have gone too far when it comes to genetic engineering.

O: I was trying to emphasize maintaining diversity, and that is what the human system does. Sexual reproduction keeps the genes re-sorting so that people are all different. The trouble is, we have reduced natural selection. The diseases used to select for vitality. As soon as your total energy reserve was below a certain level, some disease would get you. Now we have defeated most of them, so now you have to wait until something organic fails, or cancer causes the system to fail.

B: Are you saying immunizations stopped natural selection? What do you mean by that?

O: The public health and medicine has stopped the natural selection by disease, so human populations in developed countries particularly, are accumulating all kinds of birth defects more and more because there is no selection against them. In my own father's family of eight children, five survived, that was in the twenties. Now you raise one kid, and expect him or her to survive, and if the kid is defective, we keep them alive. The medical ethic cannot sustain genetic quality and a death system, but energy will. When the energy levels decrease, then everything is less including health maintenance. In our book we suggest universal health care for the basic things for everyone, but use the health insurance system for the costly items.

The advantages of this for the rich will diminish because the big differences in monetary wealth are going to disappear. Much of our money is false wealth in inflated stock markets. That money will deflate when the stock markets come down. That is a worry, how do you bring the stock market down gradually? I think we are doing it now. Does that answer your question?

B: It does.

O: Cloning and genetic engineering is just a game that people want to play. The energy involved in these things is so huge, all that is going to drop out as soon as the excess money that is in a few hands drops out. How come journalists do not know this, and how come they are spending their time with fanciful things instead of what is really important, which is the preparations for adapting us all to the new conditions ahead? The journalists are like children.

B: It would be a good thing to propose to the journalism dean.

O: I may have done that in the past, I do not know.

B: I wanted to ask you what professional activities you have planned for the future. It sounds like getting your message out is important to you.

O: Sure, at my age you have to. I live one year at a time. Priority now is getting a publisher for the new revision of Environment, Power and Society. The original publisher, John Wiley, is shifting to electronic publications, so is Elsevier, and I think they are all going to be bankrupted in a few years because cutting back on energy is going to cut back on overloaded internet archives. I do not think people can deal with whole books on-line easily. If you want to look up something, internet is fine, but it is short term memory. Ten

years from now, what is on a server now will have been replaced. It will be full of new stuff. Half or more of short term memory needs to be sifted out. The human body and brain already do that beautifully, selecting some items for long term memory as we grow up. Educated people learn how to select and to save for the long term. Our society has to do that now. Society now is in a save-everything mood. Historians can be of great help, they can get their principles for selection straight.

B: Do you feel like you have gotten across in this interview your most important ideas or lessons? Is there anything else that we should talk about?

O: We are publishing a software disk with our simulation programs and explanations in TrueBASIC. I am not sure I did what you wanted, to relate to historical events and environment of Florida.

B: You know, you did, we went through a lot. We went through a lot of events and issues, and you really had some interesting things to say about all of them. I think it will be useful.

O: I will mention a couple more. Blue Key Society (around 1978) gave me their annual award, but I was on sabbatical in New Zealand, and it was done by the time I heard. Because of that society's out of date elitist policies on race, women, and fraternities, I might have refused it had I been here--a tough decision.

President Robert Marston (president, University of Florida 1974-1984), a good president, gave me his presidential medal at the time we published Energy Basis for Man and Nature. Then he gave us $5,000 to answer the following question facing him: "Should I put

money now in a cogeneration plant at the university, or should I put it into academic honors programs?

B: And what did you say?

O: I said, okay, we will go study it. Of course, by the time we finished, we had a full emergy evaluation of the university, and it was a good one. But we realized halfway into the study that with the university, as with any system, you cannot understand one scale of system unless you see its role in the next larger scale. We had to evaluate the university's role in the state in order to decide whether the honors programs will do more for the emergy of the state than the thrifty saving of fuels with a cogeneration plant. We did not get that done in the time allocated, and he was probably disappointed with us. We gave him a report, but it did not answer his question. The university got more money, and they built the cogeneration plant and did the honors programs too. Later we related the university contribution to the Florida analysis.

B: That is an ironic story. Well, that sounds really interesting, the emergy analysis of the university. Do you remember some of the points that came out?

O: Sure. They were published in a symposium in Ohio and well summarized in this book.

B: In Environmental Accounting.

O: Yes, it has them all. For example, a good part of the emergy of the whole university is brought in with the students because they have a moderately high level of education before they come in. The emergy of utilities and water inputs are substantial, but they are not as large as the emergy in information inputs. Of course, the output

products are four: education, research, service, and public entertainment through sports.

B: It was public entertainment, education, research, and what was the fourth?

O: Service by the university professors. Presidents usually describe university purpose as teaching, research, and service. They leave out the biggest one which is information leadership, long-range leadership.

B: So you put in public entertainment and long-range leadership?

O: Of course, the sports excess needs to be fixed. One of the main emergy inputs is library information. The emergy in a book is the emergy that went into that person's training and experience and the two years they spent researching and writing. This is the emergy in the first or last copy. Now, if you make a thousand copies, that is an emergy split. The emergy is divided up. The emergy it takes to make a copy is small, but more is required to make a thousand copies and spread them all over the world, even if nobody reads it. The emergy of the original is now divided up into those thousand. If they are all lost except one copy that is left, like some book out of the Middle Ages, it gets back to the original emergy, plus what went into saving that copy all during that period of time.

The same thing works with endangered species. We can estimate the emergy it takes to develop a species from the next nearest species, although the data on time required are not very good. We evaluated a park recently; 30 percent of one endangered sandpiper's population was there, so 30 percent of the emergy

involved in that population went into the emergy evaluation of the park.

B: What do you think your impact has been so far, if you could assess that?

O: Our most valuable contribution has been ideas and many broadly trained graduates. Even Bob Costanza has done a great job in getting economists to doing ecological economics.

B: That was Bob who?

O: My former student, Bob Costanza has tried to attract money from financial interests by using their methods, although he used energy methods in the past. He opposes the word emergy as competing with his present methods. Let us see if there is anything else. Well, what did you expect to find over here today?

B: You know, you answered every one of my questions, even the ones I did not ask. You ended up answering them before I asked them, so I think it went very well. If you have one enduring message, you may have already said it, you may have already imparted it, but is there one message you would like to leave me with?

O: To do our part of the self-organizational process in fitting humanity in the earth, which includes the preservation of the most essential information. The U.S.A. needs a new motto: "Global Sharing" to replace "Anti Terrorism."

B: Well, I really appreciate your time, thank you so much.

[End of Interview]