
1997 CLARKE LECTURE

Learning and Listening About Water

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I WELCOME THIS OPPORTUNITY to applaud the late Mrs. Athalie Richardson Irvine Clarke and her daughter, Mrs. Joan Irvine Smith, for their significant efforts through the National Water Research Institute to promote better water science and technology. Early on, they recognized the vital nature of our most precious resource and have acted in most beneficial ways to protect it. I also applaud the management practices here promoted by the Irvine Ranch Water District and, indeed, practices throughout Orange County, California, to expand our ability to solve problems of water when in very limited supply. We at Stanford University have benefited greatly in our research efforts to better conserve and clean water from the support given to us by the National Water Research Institute and the Orange County Water District over the past 20 years, beginning with our efforts to help the District to characterize the effectiveness of Water Factory 21, a creation of theirs which is still the most innovative water reclamation plant of its kind in the world. Thus, I have multiple reasons to be appreciative and thankful to those here this evening.

I would like to begin by repeating the story of the two psychologists who met in the hallway after a busy day, the older one with golf clubs in hand and the younger with a strained expression. The

younger asks the older how he can look relaxed after hearing about so many problems all through the day. The older explains, "It's simple. I don't listen."

This emphasizes a theme I wish to address this evening. It often seems easier to pass through life not listening about the problems before us. When we had the Cold War, we were very willing to invest in research and development to keep ahead of the problems that this brought. But now with that concern behind us, we wish not to hear about other problems that need to be addressed, but rather find it more satisfying to assume

that life is on a good course and that we need not worry about what is to come. That

has no concern for us. The future will take care of itself. I would like to plea, however, that if we and our children are to have an acceptable future, efforts to better understand the environment in all its aspects requires more attention than ever before as population growth and demand continue to consume our remaining resources.

No resource is more precious than water.

We use it to drink, cook, grow food, clean, and carry away our wastes. We use it for cooling industrial processes, steam-electric power plants, food, beverages, and air in the home and at work. We generate power with it, fish from it, swim in it, and ski on it. Vacations are generally spent by it, on it, or in it. We obtain pleasure from looking at it, listening to it, seeing it, and tasting it. No other resource is so important to all aspects of our lives, and this has always been the case.

Unfortunately, the supply of fresh water, while vast, is nevertheless limited. The great many uses we have for water often results in greatly conflicting demands for it. Of the total amount of water in

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While he serves as the Silas H. Palmer Professor of Civil Engineering at Stanford University, Dr. McCarty is also the director of the Environmental Protection Agency-sponsored Western Regional Hazardous Substances Research Center, as well as an elected member of the National Academy of Engineering. Among his many distinctions, he holds an honorary doctorate from the Colorado School of Mines, honorary membership in the American Water Works Association, and membership in the Water Environment Federation. In 1992, he received the Tyler Prize for Environmental Achievement.

the world, only 2.5 percent of it is fresh and useful for most human purposes. Of that, only about 1 percent is truly available to satisfy our daily needs. Of significance also is that need and availability differ greatly in time and space. Floods in one location are accompanied by drought in another. Even at one location, a flood today can be followed by water deficiency tomorrow, a fact that has been very evident in recent years here in California.

Economic well being is always accompanied by an increase in the per capita demand for water. In poor countries without piped water, the effort required to carry water from the source to the home limits personal consumption to about 5 gallons per day. When conveniently available in the home, consumption for drinking, cooking, washing, bathing, and landscape irrigation increases the personal demand by 50-fold. Not surprising, then, is the fact that the increase in world demand for water during the twentieth century has been double that of the population increase.

The recent (April 1997) "Comprehensive Assessment of the Freshwater Resources of the World" by the United Nations Commission on Sustainable Development stated that "...the world faces a worsening series of local and regional water quantity and quality problems, largely as a result of poor water allocation, wasteful use of the resource, and lack of adequate management action. Water resources constraints and waste degradation are weakening one of the resource bases upon which human society is built ... Water shortages and pollution are causing widespread public health problems, limiting economic and agricultural development, and harming a wide range of ecosystems. They may put global food supplies in jeopardy, and lead to economic stagnation in many areas of the world. The result could be a series of

local and regional water crises with global implications...."

The report goes on to state that, "...Due largely to poverty, at least one-fifth of all people do not have access to safe drinking water, and more than one-half of humanity lacks adequate sanitation. At any given time, an estimated one-half of the people in developing countries suffer from water and food related diseases caused either directly by infection, or indirectly by disease-carrying organisms that breed in water and food...." These are global problems of immense proportion.

Public health and sanitation problems on this level are not the major concerns with water for us here in California, nor in the United States in general, nor in western Europe or Japan. These are problems associated with being poor, problems of the developing countries. I doubt that any of us here this evening can really imagine being so poor that we would have to make a choice between purchasing fuel to boil highly polluted water to give to our children or purchasing rice to prevent their immediate starvation. Yet, that is the plight of about one-third of the people in developing countries in the world. Yes, good water is a precious commodity, a fact that becomes very apparent if you do not have it.

But, while of a different kind, we too are experiencing water problems in the United States that require good science, good engineering, and good management. California has long been the world's leader in water conservation because water is a limited resource, and we recognized early the importance of water to growth and economic well-being. Population increase here continues as it does throughout the world, and the growing impact on our water resources is evidenced almost daily in the local press. Just this past month, an article appeared about the plans for

use of the 28,000 acres of Fort Ord land near Monterey, California, being released by the United States Department of Defense for civilian use. A major part of this plan is the establishment of a new California State University campus; however, the recent plan just released suggests the land now must be developed with a three-fold reduction over the original plan in number of homes, jobs, and people to be accommodated there, primarily because of the lack of freshwater.

Additionally this past month, the federal government revealed plans to declare the Northern California coho salmon as a species threatened with extinction. The numbers of this highly prized fish have dropped from typical numbers in the past of 150,000 to 400,000 down to current levels of about 10,000 due to over-harvesting, degradation of streams, building of dams that restrict migration for spawning, and competition from hatchery-raised fish. This action will affect about 700 miles of California coastline, as well as areas inland up to 150 miles. This decision can have great economic impact, including the restriction of logging that brings silt to the streams, new restrictions on water diversions from streams for other beneficial purposes, and the prohibition of mining in the area if resulting acid drainage will pollute streams. Because of the many competing uses we have for water, protection for one use impacts greatly upon another. These are all problems resulting from the increased and competing demands for food, fiber, minerals, and recreation as population and economic well-being grow together.

These examples illustrate the diverse and complex problems we face in water resource management. When we think of the problems that the scarcity of this precious resource will cause in coming years throughout the world, we wonder how they can be addressed adequately.



We know that to bring the developing countries out from under the extreme poverty that many face, the economic base must be greatly expanded. Such expansion always requires more water per capita. It is obvious that good science to better understand the problems, good engineering to provide alternative solutions, and sound management with the tools provided are vital to address the ever increasing complexities of water resource limitations.

Some would say the problems are too complex to be manageable and feel we are out of control with respect to our ability to protect the environment. But rather than projecting fear, I would like to offer a cautiously optimistic view of our ability to solve these problems if we are prepared to act. This past month, I heard a speech by Stewart L. Udall, the former Congressman from Arizona and Secretary of the Interior under both Presidents Kennedy and Johnson, who was a leader in efforts to protect water resources and the environment in general through many important federal initiatives and his own writings. In his speech, he called himself a “troubled optimist.” An optimist because he feels we have the ability to solve our environmental problems, and water is a vital part of the environment, but troubled at the frequent lack of interest in addressing the issues involved, or of not doing so in a sufficiently timely manner.

Such optimism as I feel about our ability to solve environmental problems was stimulated at an Earth Day conference at the California Institute of Technology (Caltech) well over 20 years ago. On that day, the late Rene Dubos — the noted microbiologist, environmentalist, and Pulitzer Prize winning author — presented

a lecture entitled, “Trend Is Not Destiny.” His talk addressed the fear of those who felt the world was coming to an end if we did not change our ways. Dubos gave various examples of how society had changed in the face of impending doom. One I remember from that day was about the increase in horse population in New York City around the turn of the century. Horses were a primary mode of transportation. The City fathers did not know how to cope with the rising numbers and felt they would soon run out of answers



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for how to not only transport the tons of animal feed required into the city, but more importantly how to clean the streets of the vast quantity of manure accumulating there and to transport both it and all the horse carcasses out of the city — and then where to put it all. I remember somewhat later when I rode a taxi with an elderly driver to the Boston airport, and as we passed through the market place near Fannie Hall to enter the Sumner tunnel, he told me that as a boy just after the turn of the century, he was brought to the marketplace there many times by his father. He talked about the unbearable flies and the awful stench

from the horse manure accumulated in piles in the market, especially in the summer heat, and how pleasant it finally became after the automobile arrived to replace horses.

Yes, it was the automobile that saved that crisis from occurring. Of course, the automobile then brought with it a whole new set of problems as population and its use grew, as we well know here in California. But the immediate crisis was averted. The unthinkable destiny from the trend in growth of animal transportation was not to be.

There are many examples of how developments in science and technology have been able to change our lives in significant ways, often averting trends towards unthinkable futures, at least for a time until once again population growth and demand present new problems that require new solutions. This is a view often expressed by economists who indicate we should not worry about resource depletion, energy crises, or global change as humans have the capability to adapt when there is a need to do so. They seem to have an unlimited faith in the ability of science and technology to solve any resource problem that may develop. They can provide us with many examples upon which to draw. I too can offer some examples that tend to support their case. But I would like to emphasize that such changes do not just happen. They require good understanding of problems, access to good alternatives, and a willingness to do something about them.

One such example I would like to relate occurred a time when I was a graduate student and then beginning professor at the Massachusetts Institute of Technology (MIT). During World War II, Germany

was faced with a shortage of fat used to make soap and so developed a synthetic detergent industry. These synthetic detergents proved to be far superior to ordinary soaps because they did not react with hard waters to produce an objectionable precipitate. They grew rapidly in popularity, a popularity that soon became evident at the biological wastewater treatment plants in cities, where mounds of foam formed on aeration tanks, some of which were 15- to 20-feet high. The foam made it impossible for maintenance crews to work around tanks, dogs fell in, and bubbles of sewage blew around neighborhoods for children to play with. Then, drinking water taken from wells near septic tanks began to appear with a head of foam, and suds were commonly found along the banks of streams where so called treated wastewaters flowed. While many efforts were being made to reduce the consequences of this foaming and to confirm that the new detergents were indeed the cause, my colleagues at MIT began studying the problem. They soon arrived at the cause. They found the new detergent molecule was made up of highly branched hydrocarbon chains, and they were astute enough to recognize that this made it difficult for microorganisms to destroy them. They suggested to the detergent companies that they needed to straighten out the detergent molecules, a suggestion that industry eventually took following political threats to ban synthetic detergents from the marketplace. By 1964, the industry changed the detergent structure, as suggested by the MIT professors, and the problem disappeared overnight. Good science led the way.

Another example I would like to relate is thermal pollution of rivers and lakes, a problem that perhaps few of you here have even thought about as a serious problem. Yet, just 25 to 30 years ago, a timescale experienced by many in this

room, the increase in the rate of electrical energy usage was very high, doubling about every 10 years. This trend was projected into the future by power utilities and felt to reflect destiny. The reported consequences of meeting this projected demand were staggering, but power industries and other experts at the time insisted we must meet that demand. It was felt that society should not be expected to curb its energy appetite and it was the duty of power utilities to meet societies demands rather than to affect a change in their behavior. Based upon these projections, 38 new nuclear power plants were to be located along the Columbia River between Oregon and Washington, and in California. By this time today, would have had a nuclear power plant every 10 miles along the Pacific Coast from Oregon to Mexico. Fully one-sixth of the nation's total freshwater runoff was projected to be needed for cooling by 1980 (that is, 17 years ago) and some rivers were projected by now to have reached their boiling point from thermal discharges from these power plants. By the year 2000, heat discharge to some rivers was expected to cause them to completely evaporate. I remember the major conferences and the research studies that were undertaken to address thermal pollution, and legislation addressing this issue was underway. A major crisis in water supply was impending.

So what happened? Why do we not hear of this problem anymore? Well, the utilities were wrong about the unyielding demand of the public. Trend, indeed, was not destiny. Citizens came to their senses when the energy crisis became apparent, urged on certainly by great increases in energy costs. Conservation of energy became an accepted principal. As a consequence, the construction and operation of several nuclear power plants in the State of Washington, for example, came to a halt, resulting in great economic

dislocation for the utilities and investors involved. In New England, the glut of power resulting from such projections caused plants to close, states trying to get out of agreements to import electricity from Canada and, in one case, a utility filing for bankruptcy-law protection.

A wonderful recent example of our ability to change when clear evidence of a problem is presented is the Nobel Prize winning efforts of Sherwood Rowland here at the University of California, Irvine, who, together with Morio Malina and Paul Crutzen, reported from their fundamental studies that a depletion of the protective stratospheric ozone layer was likely to occur from our use and release of chlorofluorocarbon gases (CFCs) used in refrigerants. They projected the trend and called for change — warnings that were largely unheeded until empirical evidence began to confirm that a significant ozone depletion over the Antarctic was, indeed, occurring. With good empirical observations and the sound scientific underpinning they provided, the 1987 international treaty known as the Montreal Protocol was developed, industry responded, and CFCs are on their way out. A recognized trend did not become destiny, and we were once again able to respond in a sensible manner. Fortunately, good science and a listening public were followed by responsible action.

I would be remiss in my listing of success stories if I did not mention Rachel Carson's effectiveness in bringing the problem of toxic chemicals to the world's attention through her 1962 book, *Silent Spring*. It provided highly convincing evidence of the destruction pesticides and other toxic chemicals were bringing to our ecosystems. Her book was neither greeted kindly by industry, nor by her scientific colleagues. They did not want to listen to her story, but the public



heard. And with that came a profound change in our thinking about industrial chemicals that is still with us today.

Without a doubt, the major reason for pressure on our vital resources is a world with too many people. In 1991 and 1992, the United States National Academy of Sciences, together with the Royal Society of London and the Royal Swedish Academy of Sciences, issued a joint statement expressing the belief that the ultimate success in dealing with global social, economic, and environmental problems cannot be achieved without a stable world population. Professor Paul Ehrlich at Stanford University has been one of the more vocal forecasters of impending doom because of our expanding world population. He effectively brought the dire consequences of this major problem to our attention through publication of *The Population Bomb* just about 30 years ago; however, in a recent interview, he admitted that the level of famine he had predicted was not correct, that the mass population die-off in the 1980s never came true, that the “Green Revolution” that helped feed more people and the rapid worldwide efforts to control population growth were technological and societal changes that he had not foreseen 30 years ago.

Yes, we have been able to change undesirable trends when we became aware of them, especially when scientists and engineers have been able to provide not only an understanding of the problem, but also have helped develop acceptable solutions. Sound information about a problem trend is the first necessary step for society to accept its reality and begin to adjust to it. Such successes, as I have noted, provide us with some optimism for the future. But we have not always

been so successful as these examples suggest. Paul Ehrlich was quick to point out that although we are, indeed, making good progress in efforts to control population growth and its potentially adverse effects, we still have almost a billion people in hunger today.

Another not-so-successful story that I would like to report is more directly related to water. Because of Rachel Carson’s book, many biologically resistant pesticides, such as dichlorodiphenyl trichloroethane (DDT), were removed from the market, but unfortunately, no



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action was then taken with other known toxic chemicals, such as chlorinated solvents. But in 1961, a year before her book was written, the United States Public Health Service — the agency then responsible for policy on water pollution control and drinking waters — also warned of the dangers of toxic chemicals at a symposium of the country’s most knowledgeable engineers and scientists gathered together to discuss groundwater quality problems. Here, it was reported that, “The pollution of groundwater is insidious ... Once an aquifer is polluted, a very long time may be required to clean it up, even after the source of pollution is removed ... A wide variety of organic contaminants are reaching groundwaters

from leaky tanks, lagoons, and septic tanks, or by accidental means. The problem is nationwide ... Knowledge of time of travel and geology, of biological and other effects, of saturated and unsaturated aquifers, and of soil types, as related to organic contamination of groundwaters, is limited. Concerted effort is needed to extend this knowledge.” Identified as common contaminants at that meeting were essentially all of the now commonly recognized groundwater contaminants, including pesticides, chlorinated solvents, and petroleum hydrocarbons. The report contained a strong plea for the funding of scientific research to understand the nature of the growing problem.

That plea was essentially ignored for 20 years, until well after 1978, when the Love Canal incident brought to the public’s attention that the earth’s mantle was the rug under which we were sweeping our waste chemicals since earlier environmental legislation said we could no longer put it into our rivers, oceans, or air. Trying to clean our soils and groundwater of this legacy to the degree that society not only would like, but is demanding, carries a price tag estimated at \$1 trillion. This represents a cost of \$50 billion for each year that we ignored the problem. How much wiser it would have been to invest just a small part of that into groundwater research and development, and then to put our efforts and money into prevention rather than expensive cleanup? Preventive measures are not expensive. They include building storage tanks that do not leak and the recycling of solvents instead of throwing them away — measures that involve trivial costs compared with the millions of dollars required to clean up contaminated groundwater from just a single leaking tank.

The clean-up problem is enormously complex and, indeed, as a result of recent good science, we have found out just how complex and expensive this problem really is. There is considerable doubt now, even if we spent the trillion dollars estimated, that the problem would be solved. Chlorinated solvent contaminants have penetrated so deeply below the earth's surface and have spread in such undefined manner that, in many cases, we will not be able to render the soils and groundwaters pure no matter what we do. We have about accepted the fact that in many cases, our only real alternative is to restrict properties for industrial usage only, and to recognize that the lands upon which such industries may sit will be hazardous over our lifetimes and of our children's and their children's as well.

These several examples serve to illustrate how we have frequently been successful in changing adverse trends but, at times, we have not been so successful or, often, our success is only partial or not reached in a timely enough fashion. An adequate solution to a complex problem demands good vision of the future since the changes needed are often so great and the impacts of needed change are ever so much more difficult to predict. Such vision requires the understanding that scientific and engineering research can bring.

My desire here tonight is to convey to you the great importance of protecting and adequately managing our precious water resources because of the greatly growing competition for them, and also to convey a cautiously optimistic view of our ability to do so. But like each of our major resources, the ability to manage one well is intricately interwoven with our ability to manage all of them well. They are inseparable and, ultimately, linked together with the growth of the human population and its needs.

Of all the thousands of wonderful species that have evolved in this world since life began some 3-billion years ago, it is only the human species that has the power to see into the future and to speculate upon what it holds for us. We are also the only species that has the power to change that future. That power has allowed us to dominate the earth. But while we can look into the future, our vision of it is not very clear. This causes great uncertainties for us and, as a result, we have many scientific and political debates about what we are actually seeing. When the Hubble Space Telescope was lifted into orbit by the space shuttle *Discovery* in April 1990, it had a deformed mirror that pulled a lace curtain over its ability to see. But just a few years later, in December 1993, when the crew of the shuttle *Endeavour* was able to correct that flawed vision, we were suddenly able to see to the very edge of the universe. But that was a relatively simple thing to do. Our task here on Earth is a much more difficult one. If we are to see our future well enough, we must learn in much greater detail of the complexities of how the chemical, physical, and biological processes on Earth interact to maintain the diverse ecosystems upon which all of life here depends. Only through such understanding can we have hope of clearly seeing the Earth's future as the Hubble Telescope has been able to look into the depths of the universe. That is why the need is so great to place an increasing emphasis on scientific research about the natural processes occurring here so that the vision of our future can be clearer and our decisions about it can be wiser. The call is for science to understand nature rather than to exploit it. And with that improved vision will come a greater need for the development of technologies, not any technologies, but the kind that will allow us to achieve a future where all human

societies can come into a long-term equilibrium with all the other living creatures upon which we depend.

I am making this plea because of the growing trend I see to downplay the importance of education, universities, and scientific and engineering research in cities, states, and the federal government. The strong commitment that we had to knowledge and education during my entire professional career seems to be coming to an end. Fewer federal dollars on an inflation-adjusted basis are now spent on non-defense related research than 30 years ago when I was just started teaching at Stanford University. Federal research dollars have dropped 10 percent on a real basis just since 1990 and are expected to drop an additional 14 percent over the next 5 years. And, these decreases come at a time when we have no major battles with other countries to wage and when national wealth is at an all-time high. It is most discouraging to our young science and engineering faculty members when only one out of every 20 to 50 proposals they submit get funded for research. In so many instances now, the total effort placed in generating proposals and having them peer reviewed far exceeds the dollar value of the research that is supported. This is no way to avail ourselves of the intellectual capital we have in this country, nor to solve our problems of the future.

If we are to meet the future and its demands adequately, then we need to open our minds and learn more about the problems that are coming. As a final example, one such important issue upon which we are yet to act is that of global warming. The scientific community now generally agrees that global warming is a fact. If the forecasts being made with less than perfect models truly represent the path we are upon, the impact on water



resources and their distribution will be great. We need to learn more about this. Climate changes that support such model predictions are now discernible. Wider variations in weather patterns that we are now seeing throughout the world are predicted by global warming, but we are not yet sure whether this represents just random noise or true effects from the known increasing level of carbon dioxide in the atmosphere. The international scientific community, as well as that of the United States, suggest that the prudent course is to begin now to reduce our use of fossil fuels. The insurance companies certainly are beginning to listen. But like the older psychologists with his golf clubs, many others prefer not to hear. Indeed, some prefer that our vision of that future not be improved. Like all major changes that society has made when it recognizes an adverse trend, great economic

dislocations will result. Those who are likely to be impacted most and have the most to lose will resist the changes. But, in the long run, if changes are not made at a time when it is easier to do so, the cost to society as a whole will be even greater.

In summary, there are three messages that I want to convey this evening. The first is that a continuously increasing world population will result in an ever-increasing demand upon our resources, including water, and for this we must be prepared. The second is the great importance of scientific research on environmental processes so that we can better see the impacts of what we do, and engineering research to provide a broad range of alternative choices so that we can better direct the future towards a healthier one for humans and the ecosystems upon which we depend.

The third is to encourage a more openness towards the findings of science regarding the environment so that changes can be made in a more timely manner, thus greatly reducing their costly and adverse impacts. If we are willing to listen to and learn about these major issues, and are open to acting upon them in a serious manner, then we have every reason to be optimistic about the future. Lastly, I wish to again thank those of the National Water Research Institute and Mrs. Clarke and her daughter for their significant efforts to address all of these causes. And to thank all of you here for listening to my concerns and pleas about the valuable resource with which we are here tonight primarily concerned — that is water, a resource worth learning and listening about. Thank you all for this very pleasant opportunity that you have afforded me this evening.

