

Water Resources Research Institute
School of Engineering
University of Puerto Rico
Mayaguez Campus

RESEARCH PROJECT TECHNICAL COMPLETION REPORT

Project A-040-PR

PUERTO RICO WATER RESOURCES PROBLEMS AND RESEARCH
NEEDS - PROCEEDINGS OF CONFERENCE AND PLANNING
SESSION*

By

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FOREWORD

The First Conference and Planning Session on Water Resources Research Needs, sponsored by the Water Resources Research Institute with the cooperation of the Commonwealth Department of Natural Resources, was held at the University Library of the Mayaguez Campus on February 14, 1974.

In attendance were more than 50 persons related with our water resources including the Honorable Secretary of Natural Resources, members of the Commonwealth Planning Board, Commonwealth and Federal agency heads, and leading professionals and scientists of the University community, and of the private and public sector.

The scope of this Conference was to set the basis for a series of workshops to follow to identify the island water and related-land resources problems and the research needs in order to prepare a problem-oriented water resources research program for Puerto Rico.

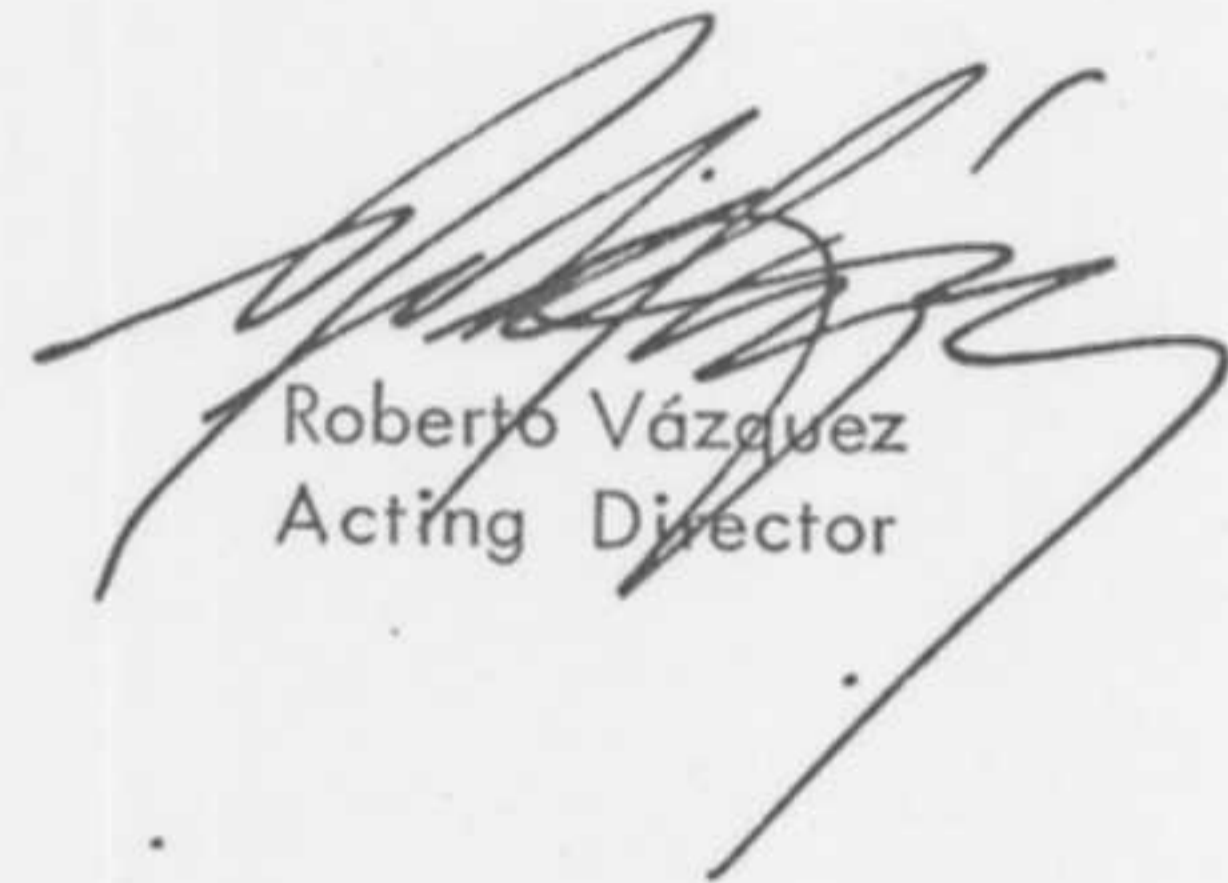
The papers presented and the discussion that followed gave the opportunity to researchers, action agencies, and water resources users to discuss their own problems and possible solutions to these problems. It also gave us a clear idea and a good source of information of the water and related-land resources problems that we are facing today and will face in the near future in the island of Puerto Rico.

In the workshops to follow, these problems and additional water problems that maybe presented, will be fully discussed to identify the research needs and set the research priorities necessary to solve the identified problems.

These Proceedings are published by the Water Resources Research Institute with minimal editing of the transcript prepared from the taped recording of the Conference.

The principal speakers were given a chance to edit their papers as were session chairmen and identified participants who had lengthy comments.

The assistance of Mr. Miguel A. Vargas in the translation of the original transcript is deeply appreciated.



Roberto Vázquez
Acting Director

CALL TO ORDER - Dr. Roberto Vázquez, Acting Director, Water Resources Research Institute,
University of Puerto Rico, Mayaguez Campus.

Good morning, ladies and gentlemen. We are pleased to have so many people from different agencies related to water resources here in Mayaguez today, although I know there have been a lot of problems to get to Mayaguez with all those strikes going on. This is the reason why we can't have with us the Acting Chancellor, Prof. Luis Angel Rodríguez, who was supposed to give the welcome address. Dr. José Martínez Picó, Dean of Studies, is representing the Chancellor and I know that he will be pleased to welcome you to the Mayaguez Campus.

WELCOME ADDRESS: Dr. José L. Martínez Picó, Dean of Studies, University of Puerto Rico
Mayaguez Campus.

Good morning to everyone. I am really pinch-hitting for Luis Angel Rodríguez, the Acting Chancellor, and I really mean pinch-hitting, he just came in five minutes ago and gave me his speech. So, here it is.

In the name of the University of Puerto Rico, Mayaguez Campus, it is a great pleasure to welcome you on this occasion. We hope that this meeting results in a most productive effort toward the development and improvement of a research program, especially in the area of water resources. Puerto Rico is a very special case, for the natural resources are very short and the human resources are very abundant. But for some reason, these human resource has not been utilized to their maximum capacity. At this point I must quote the President of the University of Puerto Rico, Dr. Arturo Morales Carrión, who said: "There is no other wisdom than the wise use of our talent and abilities. Even more vital than the wise use of our natural resources is the wise use of our human resources. So much so because well-trained human resources will take care of natural resources for to invest, invent, is to achieve a multiplier effect". But we have to equate this with real needs and objectives. The scope of this conference is to serve as the basis

for a series of workshops to be conducted in the following months in order to identify the island water resource problems and the research needs to solve these problems. Our aim is that at the end of these series of workshops to come out with a water resources research program responsive to our needs. I hope that this conference will serve the purpose of arousing interest among the University community, as well as the government officials and the private sectors in solving the water resources problems that we face today. In the same way that the meetings held by this same Institute in the late 1960's under the able leadership of Dr. Antonio Santiago Vázquez did with regard to the natural resources conservation and the environmental quality problems. As some of you may recall, that series of conferences gathered together, the same as we have here today, the most talented and interested group of scientists, students, government officials, and other concerned citizens who discussed the water and environmental problems that we were facing at that time and the ones expected in the near future. Experience tells us that they were right in their understanding. In the last few years, we have had the sad experience of observing that what these people predicted at that time came to be true.

On the other side of the coin, we have the wonderful experience of observing the solid steps that were taken in the positive side... to protect our natural resources and our environment. Good examples are the environmental concern and participation that were developed in our community and the legislation that was enacted of paramount importance like Law 158 of 1968 creating the Area of Natural Resources within the Department of Public Works that later became the Department of Natural Resources. As you, well know, the facts of the economic development and the great technological advances experienced in Puerto Rico in the last decades have created new and more serious problems which must be dealt with. Here at the University we have the scientific and technological know-how to attack these problems. It needs your cooperation, not only in identifying them but in trying to solve them as well. The Water Resources Research Institute although it has established an excellent record in the quality

of research in the past, the research program has not been sufficient to satisfy the Island needs; and this is partly due to insufficient funds and partly to the unsolicited method of research. This method of research has much merit due to the introduction of new and innovative ideas, but sometimes fails to solve your problems, the community problems, our problems. This is the reason why we are here today. To work together looking for the solution of problems that affect all of us. I am looking forward for the success of this conference and the subsequent workshops, and I deeply thank you for being here today. Thank you.

OPENING REMARKS - Dr. Roberto Vázquez, Acting Director, WRR

As you all know, the increasing affluent population, an expanding industrial economy base, and a growing concern of environmental quality has put new demands on Puerto Rico's water resources development. Water management depends on successful planning in response to public aims. Planning today in the face of the often great gap between conceptions and fulfillment of major resources development as well as the life of structural alternatives, require improved means of predicting conditions, and consequences of particular courses of action, more accurate forecasting and technological advance and the formulation and comparison of different alternative means. As can be expected, one of the basic needs for a comprehensive water resources planning and management program is the appropriate availability of hydrologic, economic, legal and social data. And this is the objective of this conference, and a series of workshops to follow, 1) to discuss the water resources problems and policies; 2) to learn about these problems and arouse the interest among the University community, researchers, government officials, water users and the public in general, in order to look for solutions to common problems and 3) working in an inter-disciplinary way to prepare a water resources research program for the Island of Puerto Rico, capable of solving the identified problems and policies.

Having these objectives, this conference is going to be conducted in different panel

sessions. Two sessions will be conducted during the morning and two sessions in the afternoon. Since we have so many people participating in this conference, we arrange to have only a ten-minute presentation from each panelist. I realize that 10 minutes is a rather short time to present all your water resources problems; but later on we are going to have a series of workshops in order to discuss more fully the presented papers.

If we work close together with the different agencies, with the water users, and the private sector, we can work out a good program for the island research needs.

Your suggestions on how to run these workshops will certainly be welcome. I think it's something new for us and although we have had some experience in similar workshops in the States; we need to apply them to Puerto Rico's conditions. So, not taking too much time since we are already behind schedule, let's have the first panel discussion. "Water for Agriculture". This session will be chaired by Dr. Fernando del Río, professor and Director of the Office of Programs and Plans at the College of Agricultural Sciences of this University.

First Discussion Panel

"WATER FOR AGRICULTURE"

Moderator:

Dr. Fernando del Rıo, Director
Office of Plans and Programs
College of Agricultural Sciences
University of Puerto Rico, Mayaguez Campus

Participants:

Agrc. Ismael Ramırez Murphy, Executive Secretary
Agricultural Advisory Committee
Commonwealth of Puerto Rico

Eng. Pedro Catoni, Staff Engineer
Soil Conservation Service
U. S. D. A.

Mr. Joselo Sanchez, Assistant Executive Director
Sugar Corporation of Puerto Rico
Commonwealth of Puerto Rico

FIRST DISCUSSION PANEL - "WATER FOR AGRICULTURE"

Dr. Fernando del Rfo, Director
Office of Plans and Programs
College of Agricultural Sciences
University of Puerto Rico, Mayaguez Campus

INTRODUCTION: - -Panel Moderator

I would like to emphasize the special importance of water resources for Puerto Rico and primarily for agricultural uses. It was not until recent years, that we realized that water was a limited resource. It is not the old concept that views water as a permanent and unlimited resource. Today we are entering into a competition for the use of the resource with other sectors of the socio-economic development of Puerto Rico such as industry, commerce, and housing. Agriculture is now suffering the scarcity of water, a scarcity problem that is expected to become more serious in the future.

This morning three distinguished speakers will talk about the subject, "Water for Agriculture", in terms of the new technological findings, and of the research needs in this field which might help to solve today's problems and those of the future. Now, I am glad to introduce the first speaker at this panel, Mr. Ismael Ramirez Murphy.

Projection on agricultural production for years 1984-85 made by the Bureau of Statistics of the Department of Agriculture show that the water needs in the three existing irrigation districts would be about 270,000 acre-ft/year, to achieve the expected goals. However, the total amount of water available is about 220,000 acre-ft/yr, which reflects a deficit in the quantity of water required for irrigation. In other words, lands provided with farm irrigation facilities will not receive the water required unless the system capacity could be expanded. On the other hand, it is important to point out that farmers do not use efficiently the irrigation water when it is available. It seems necessary to intensify education of sound irrigation practices and its advantages in agricultural output. Actually, there are various irrigation methods which are not well known by the farmers which could help them to economize water and to develop more efficient water application systems.

Another problem which faces and forces the farmers to reduce the application of water to their crops is the cost to be paid for this item. Also maintenance and conservation costs of irrigation facilities have substantially increased. It is known that the Puerto Rico Water Resources Authority does not cover the operation costs of the irrigation systems with the income obtained from irrigation water services. The annual deficit that the Authority incurs for such services is paid from the 5 percent surcharge on the total income from the sale of electricity that the Authority has to pay to the Treasury Department. This figure is estimated to be 2.3 million dollars for the year 1973-74. The absence of an adequate water supply to satisfy the domestic and other needs associated with our socio-economic development stresses the need to develop new sources of water and to make a more efficient use of the available resources.

It is important to assign the amount of water needed for any particular activity according to priorities. It is also urgent to continue and reinforce research in such areas

as sea-water desalination and weather modification. The reuse of adequately treated waters represents a potential solution of the problem of the scarcity of water for agriculture and should be studied. Among others, the following problems and research needs should be considered: new sources of water, expansion of the existent irrigation facilities, desalination of sea water, weather modification, education on irrigation practices for the farmers, reuse of treated waters, supplementary irrigation facilities, and protection of the river basins.

We have intended to present briefly the various problems that face agriculture today in respect to an adequate water supply. The picture is not very optimistic and it could become worse with the greater demands for water and land resources associated with increases in population and family income. However, making rational use of scientific knowledge and modern technology, together with appropriate management we can adequately supply the demands for these resources.

FEDERAL SOIL AND WATER CONSERVATION PROGRAMS
FOR PUERTO RICO

Eng. Pedro Catoni, Staff Engineer
Soil Conservation Service, USDA

The Soil Conservation Service is a technical agency under the Department of Agriculture of the United States which has the responsibility of helping farmers in the control and protection of water and related land resources. Some federal programs in this field are administered by our agency. Among those programs I want to mention the Soil Studies Cooperative Program. Under this program a detailed study of the soils of Puerto Rico and the Virgin Islands is being made. Ninety percent of the total area of Puerto Rico has already been studied. In the American Virgin Islands the study has also been completed and the final report published. In Puerto Rico only the final report of the Lajas Valley area has been completed. The Soil Conservation Service give technical assistance to about 6,000 to 10,000 land owners (private and public) annually in Puerto Rico. This phase of our program includes planning, design, construction, inspection of soil and water conservation practices, and technical help in the establishment of farm irrigation systems. Precisely, one of the various and important research needs we face is in the field of irrigation and drainage.

In Puerto Rico, there is very little information in respect to soil infiltration rates, water needs, and irrigation requirements of different crops. In cooperation with the Agricultural Experimental Station of Puerto Rico we have developed some technical guides, but still we need more research in this field. In cooperation with the Commonwealth Department of Natural Resources we have the watershed protection and flood prevention program.

In respect to watershed protection programs, six applications have been made in the whole island of Puerto Rico. Of these, three of them already have the written program; the rest are in the early planning stage. The watersheds under study are Añasco River Basin, Guanajibo River Basin (Bajura Watershed), Guayanes River Basin in Yabucoa, Llaurel River Basin in Arroyo, and Culebrina River Basin in Aguadilla whose application has not been approved. Another very important program we have in Puerto Rico on a voluntary basis is the erosion and sediment control on land development and construction. Erosion and sediment control is one of our more serious problems in Puerto Rico. There is still another program that we are applying, e.g., the Resources Conservation and Development Program, created by a public law of the U.S. Congress whose purpose is to help the communities to solve their resources conservation problems. Under this program only one project, "Caribe C & D Program Project" has been submitted for approval to the Secretary of Agriculture of the United States.

Under the River Basin Program, in cooperation with the Commonwealth Department of Natural Resources, we are doing some soil and water resources studies in different areas of Puerto Rico. In this respect working closely with the Soil Conservation Districts and with the assistance of the technical and professional personnel of the Department of Natural Resources, we are in the process of preparing an inventory of the potential sites for water storage in Puerto Rico. This work has been done for about 70 percent of the total area of the island, selecting the possible water storage sites for different purposes like irrigation, recreation, flood prevention, domestic and industrial uses.

In general this has been a summary of the program being conducted by the Soil Conservation Service in Puerto Rico.

WATER RESOURCES NEEDS FOR SUGAR PRODUCTION

Mr. Joselo Sánchez-Dergán
Assistant Executive Director
Sugarcane Corporation of Puerto Rico

During the year 1971 in a work assigned to me about planning at the University of Puerto Rico, I selected the following subject: "Is there any Agricultural Planning in Puerto Rico"?

After working on the above subject we found that there were no plans made in order to find out the maximum agricultural yields of products grown in Puerto Rico and specially on the sugar cane industry.

In addition to the area required for the production of a pre-determined amount of tons of sugar, we found that water is one of the most important elements in the production of sugar cane. We are talking about the Gran Sur which is an area that starts at Guayama and gets as far as Añasco, in other words, an area that produces 60% of the total sugar production of Puerto Rico.

The result of our analysis on the subject was that there was no agricultural planning in Puerto Rico and not enough interest in the role played by water in the agricultural production, specially in the production of sugar cane. In the previous Land Authority and now the Sugar Corporation of Puerto Rico we have made some efforts, but most of them separated from one another, to follow certain plans but only in a 4 or 5 years span. Our first step in 1967, was to contract the services of some technicians with expertise in irrigation, water control, and drainage. We brought Messrs. Lyons, Silva, and Jack Woerner who were graduates from the University of California at Davis. To each one we assigned one of our sugar cane areas.

We also made studies of the groundwater resources that was extracted from deep wells at Guánica and Ponce. These studies were made by the professional firm of engineers Quiñones

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and Associates. Dr. Lyman Willarsdson, a distinguished professional that once worked for the Experiment Station at Lajas and for the College of Agriculture and Mechanical Arts at Mayaguez, also came to Puerto Rico at our request. He gave us information on the quantity and quality of water available in each sugar production area and the amount of water needed to get maximum production of sugar.

Plans were made to start immediately the infrastructure needed to get our goal and also on the improvement of the application of water through irrigation.

Years has passed by and its look to us that still we are at the starting point.

The agricultural area that we designate as the Gran Sur covers about 75,000 acres of sugar cane. Studies made by Dr. Vázquez and Eng. Ortiz Vélez indicated that to get a normal production of sugar the amount of water needed is 75 in. yearly. Twelve months is the growing period of the sugar cane.

Actually we only have an average 20 inches of rain yearly in the Gran Sur Area. In order to get the 75 inches needed for the normal production of sugar, we must use 55 in. of water through irrigation. The truth is that in practice and in addition to the 20 inches of rainfall, we apply only 20 more inches of water through irrigation. We get this data from experience because only in a few places we really are able to measure the amount of water applied to the sugar cane through irrigation.

The lack of enough water for the irrigation of sugar cane, is the result of the poor yield of sugar cane at the Gran Sur Area. The yield today is only 28 tons per cuerda. If the required amount of water is applied to the sugar cane at the right time, yields of about 45 tons per cuerda could be produced. The difference of 18 tons per cuerda that is not being produced now, because of lack of water, means that the Government of Puerto Rico is not receiving about 40 millions dollars.

The prices of sugar is continuously increasing and this means that agriculture and

sugar cane, in particular, needs more attention. This will also mean that men will go back to living with nature, that means the sun, sky, the earth, and water. This will mean a more relaxed way of life, more secure, and more healthful.

These experiences that are more of the intellectual type than of the technical type, originated at Venezuela from information that they obtained last year when they decided to re-examine the agricultural production of the whole nation since now that they are getting more income from their oil deposits.

Among the intellectuals that commented on this problem of Venezuela is the world famous philosopher and thinker Arnold Toynbee. Venezuela had decided to make plans now because they know that the wealth coming from the oil deposits has a limit. Now they can afford to develop the agriculture to a maximum capacity, so that when the wealth they get from the oil deposits is exhausted by the year 2003, agriculture will take over the continuing economic development of the country.

If our government and its agencies responsible for the development of agriculture, decide to study the impact of an income of \$40 millions more, resulting from the more sugar yield per cuerda, we will have to study the possibility of getting more water for irrigation from the subsoil and other sources.

Other point that we will have to consider is the need of qualified technicians to implement the modern methods of using water needed for the sugar cane. I did not mention previously that 20 inches of water are lost due to incorrect methods of irrigation.

The technical advance that had affected and revolutionized our way of life during the last decades, have not been applied effectively for a more efficient use of water in agriculture. We need this help from our government now, tomorrow will be too late. In the next meeting I will not be talking to you in relation to the effective use of water in sugar cane. By that time probably we will not have any sugar cane.

We all should be using our land, our water, and our sun as efficient as possible, so as to get the best yield of sugar per acre for the good and benefit of our Puerto Rico.

We will do it, with your help. Thanks you.

DISCUSSION:

Prof. Leandro Goicoechea - Professor, Civil Engineering Faculty, Mayaguez Campus.

I want to bring out certain particular considerations about the water problem in Puerto Rico which have worried me for a long time. Precipitation occurs in excess in Puerto Rico, 60 inches of rainfall is by far a sufficient amount of water if we could avoid the losses caused by the water running to the sea. Thus the solution to the water problem is not desalination; it is to avail all possible water storage facilities. Unfortunately, precipitation occurs in Puerto Rico in definite periods through the year, flooding our rivers which at the same time carry this water to the sea. Hence, our problem is not the absence of rainfall; it is to control the runoff. We can not allow that all the water that falls, go back again into the sea. We must face the problem of how to use the rainfall water throughout the year. We must find the way to retain those waters not by means of artificial reservoirs whose construction is not feasible today but inducing the ground recharge wherever this could be possible. The objective, then, is to store water in some way so it could be used when and where it is needed. In any way it implies the use of the ground water which, by the way, constitutes an important source of water that still remains almost undevelopable.

Dr. Fred Soltero - Professor, Chemistry Department, Mayaguez Campus.

I would like to know if there exists some type of qualified inventory data amount of runoff that annually reaches the sea.

Mr. José Martínez Laboy - Commonwealth Department of Natural Resources

The Department of Natural Resources have estimated the runoff percentage that enters the sea, but no specific studies have been made in such respect.

Eng. Hernán Rodríguez - Engineer, Puerto Rico Water Resources Authority

I want to explain the following upon the question presented by Dr. Soltero: We in the Puerto Rico Water Resources Authority have accomplished the gathering of data related with the over flow in various dams of Puerto Rico. It must be clear that this data refers only to the waters overflowing the dams for the periods in which it occurs. We also realize that downstream new waters from other sources increase the water volume reaching the ocean waters. The data we have is available and contains records from the year of 1914 when the South Coast Irrigation System began its operations. We would also be very glad to give such information to the Water Resources Research Institute.

Dr. Ariel Lugo - Commonwealth Department of Natural Resources

I want to express my point of view on this matter of the water running off to our coastal waters. We cannot absolutely say that the water that flows to the sea is completely lost because we must have in mind the very famous hydrologic cycle of water. As water flows from the mountains to the sea, many works are being completed for the benefit of man. Coastal runoff helps to keep our estuaries, recharge the ground with water and makes other works which have to be considered in the planning of the resource. Inadequate land use in our river basins influences the rise in the annual drainage of water. This situation compels us to make better planning of our resources. Thus, we can see that the net flow of water to the sea depends on many conditions. So it is a variable, because as land development increases on the basin area upstream, the erosion increases and disturbances in the hydrologic cycle are attained. Since waters, instead of percolating into the ground to recharge the aquifers are now running off to the sea, those waters are really lost. There we must make and adopt wiser decisions regarding land-use planning to achieve the occurrence of a normal runoff to

the sea to which the natural systems are adapted, thus avoiding any excess in runoff due to unusual land development upstream.

Prof. Luis A. del Valle - Professor, Civil Engineering Faculty, Mayaguez Campus

From my point of view, one of the greatest difficulties encountered by the researchers in the field of water engineering in Puerto Rico is the scattering of water resources data. Certainly some important agencies as the Puerto Rico Water Resources Authority, the Aqueduct and Sewer Authority, the Geological Survey and the like have gathered and accumulated a considerable amount of data regarding water resources. But, again those records are so scattered among the agencies of the island that they cannot be effectively used in most instances. Thus, one of the larger obstacles we must overcome to make more adequate planning decisions is the recopilation of all the data which has been recorded in Puerto Rico. Even today, at the very moment I have no information of any effort toward the development of a systematized procedure involving the arrangement of hydrologic data for further analysis, so these records could be easily available to the people requiring them. I would like to suggest that after recognizing the extreme importance of water, the Department of Natural Resources create a division which undertake the works for the collection of data to increase the usefulness of those records, constituting a partial basis of future water resources planning decisions.

Mr. José Martínez Laboy - Commonwealth Department of Natural Resources

Recently, a systematized Hydrologic Data Bank has been developed and instituted by the Department of Natural Resources. The data involves records upon climatological and hydrological parameters and new variables related to topographic features, and soil composition will be added. An inventory on natural resources has also been made by our Department to serve as a complement of the hydrologic data bank. In such inventory the land use patterns,

slope characteristics of the terrain, and the type of soil and subsoil have been taken into consideration.

Mr. José A. Pesquera - Member, Soil and Water Conservation District, Utuado

I have understood that the gathering of data will be done in order to have the necessary records to plan future program in soil and water conservation. I am deeply worried by the negative effects which have resulted by the indiscriminate remotion of land affecting our basic natural resources.

The cutting of trees is extremely dangerous for the conservation of soil and water resources. An area where the cutting has been greatly exaggerated must be declared an emergency zone; hence, as it was already mentioned, as the development of land increases along the river basins, the water available will be less.

Dr. Fernando del Río - Panel Moderator

I truly believe that this panel on Water for Agriculture has been very successful. The contribution of all participants has been excellent. I want to express to our three panelists our most sincere thanks for their presentations: Mr. Ismael Ramírez Murphy, Mr. Pedro Catony and Mr. Josélo Sánchez. Similarly, I want to welcome to this conference our ex-chancellor, Dr. Fred Soltero Harrington, who gave a great impulse and support to the Water Resources Research Institute. Again, thanks to all of you.

Second Discussion Panel

"WATER FOR DEVELOPMENT"

Moderator:

Dr. Antonio Santiago Vázquez
Professor of Civil Engineering
Faculty of Engineering
University of Puerto Rico
Mayaguez Campus

Participants:

Hon. Cruz A. Matos, Secretary
Department of Natural Resources
Commonwealth of Puerto Rico

Eng. Pedro Mora, Associate Member
Planning Board
Commonwealth of Puerto Rico

Eng. Juan M. Olivieri, Technical Assistant to the Secretary
Department of Transportation and Public Works
Commonwealth of Puerto Rico

LTC. James M. Scott, Deputy District Engineer
for Puerto Rico and the Virgin Islands
Corps of Engineers

Dr. Raúl Filardi, Sub-Director
Planning Area
Puerto Rico Aqueduct and Sewer Authority

SECOND DISCUSSION PANEL-"WATER FOR DEVELOPMENT"

Dr. Antonio Santiago Vázquez, Professor, College of
Engineering, University of Puerto Rico
Mayaguez Campus

Panel Moderator

INTRODUCTION

It was nine years ago, a morning in February 1965, when we began to hold a series of conferences which further became a series of annual discussions on water resources in this Campus. The first of those conferences was initiated with an invitation to the directors of all agencies related with water resources in Puerto Rico. Those set the basis for further conferences and programs which have been developed in Puerto Rico. It also pleases me that the Water Resources Institute, under Dr. Vázquez's leadership, has re-initiated this type of activity, which I hope will provide the forum for the discussion of recent experiences and new ideas.

Dr. Roberto Vázquez has titled this second panel "Water for Development". In fact one of the first reports made in Puerto Rico on water resources was submitted by the Water Resources Committee in 1966 to the Honorable Commission of the House of Representatives on Natural Resources and Environmental Beauty. I want to proceed in quoting the forewords of this report that I consider of tremendous importance: "The water resources serve the fundamental basis for the development of any nation and its people. Hence it is of paramount importance to be developed under the most adequate management and administrative procedures to guarantee its optimum use. The history of man is one being developed close to the rivers, that means that man's own development through history is completely linked to the development of water resources. Due

to the complexity of today's development; the development of the water resources becomes an integral part of Puerto Rico's total development. We could not undertake any agricultural or industrial development program unless we could provide water in adequate amounts and quality in the place of development. In fact, our development today, could be seriously threatened by the inability of having the resource in the required quantity and quality in the proper place, an experience that we have had already."

But, to listen to the plans and worries of our government, and to point out the problems where the University and other participants could contribute in their solution, let's have the first panelist of this section, the Honorable Secretary of the Department of Natural Resources, Mr. Cruz A. Matos.

WATER RESOURCES FOR DEVELOPMENT

Hon. Cruz A. Matos, Secretary of Natural Resources
Commonwealth Department of Natural Resources

Traditionally, water has been considered a good whose value could be measured in terms of the use that man gave it. From this point of view the water that flows to the estuaries and swamps and eventually to the sea is wasted. The common water planning procedure follows this concept, so it focuses the philosophy of managing water resources for man's direct and immediate benefits. For this and further conferences we should ask ourselves if this is the correct approach to the problem, and if this approach could lead us to permanent and long range solutions, or are we ignoring some critical aspects which could limit our future development and the quality of life.

Let's consider the following facts:

1. The amount of rainfall in a given area, which is in turn the available source of supply for human consumption is a measurable and limited quantity.
2. The rainfall maintains the ecological systems, the chemical cycles of matter, as well as the urban systems.
3. Man can't have a high standard of living, a good quality of life, and other free gifts of nature like pure air and recreation, if water and other natural resources are limited.

Therefore, to keep man and the natural resources healthy we should plan water uses not only for the benefits of man but for the natural systems as well. If it is not done in this way, when the natural systems are affected, man will suffer the consequences. The water that reaches the sea is not lost since it carries sediments to feed our beaches, nutrients for our mangroves swamps, and dilutes the sea water in our estuaries for an optimum marine life.

The Natural Resources Department policy is that man has to consider the natural ecosystems demands in planning their water needs. We hope that this conference will generate the development of proper strategies to attain the optimum balance between nature and man.

ROLE OF WATER RESOURCES FOR ECONOMIC DEVELOPMENT

Eng. Pedro Mora, Associate Member
Planning Board
Commonwealth of Puerto Rico

As we all know, in any society, the water resources play an important role by maintaining the processes of life in nature and constitute a factor of vital importance in the Development of Agriculture and industry. Besides, water resources represent a great potential for the development of recreation facilities and become a primary need for any human activity on the planet. We recognize that the society in which we live is within a process of economic development, and that the availability of water resources is of fundamental importance to permit the undertaking of those plans which are necessary to support such development. To me, the availability of water includes not only its quantity, but its quality, the collection and distribution systems, and the final disposition of waste water, all in accordance with appropriate health and environmental standards.

In the case of Puerto Rico, at the beginning of our economic development in the year 1940, there was little concern with water resources problems, as we see them today. At that time, with the exception of some particular areas, water resources were relatively abundant to satisfy the requirements of municipal supply, industry, and agriculture. In those years, agriculture exerted the larger demand for water. That major water use, land irrigation, represented an artificial recharge for the aquifers whose waters in turn were used for domestic purposes.

Since that time, the industrial demands have increased sharply and some parts of the island face scarcity of water, particularly in the south coast. The Planning Board in its overall planning role, the physical, social, and economic development aspects, recognizes the need of adequate supplies of water for human consumption, agricultural and industrial uses, tourism, and all other economic activities.

Recently we have recognized the need to be more self-sufficient in the area of agricultural development. We have had the problem of an insufficient food supply caused by a decrease in the productivity of our lands which demand more water for irrigation.

At present, the pressures upon our water resources are of such magnitude that compel us to protect them by developing a conservational policy. Water is a very important element in daily life, hence, it should require protection against unnecessary pollution and indiscriminate uses. We have seen in recent years how an important aquifer in the north coast was almost destroyed when it was used for the disposal of industrial wastes. Sewage and industrial waste pollution in our rivers together with poor practices in land use planning create the need to undertake rigorous action upon such problems.

In the other hand, in the use and conservation of our water resources, we have adopted technology and criteria from other parts of the world which do not necessarily apply to the characteristics of our environment. This is a major point I want to discuss today. Puerto Rico is a small island, overcrowded, with limited natural resources. Our topography restrains the development of projects to conserve water resources. Urban growth and the absence of sewer facilities in rural areas are the principal causes of pollution in our bodies of water. Traditional methods to reduce water pollution by treatment do not operate in rural areas, or the implementation of such methods implies very high costs. Thus, how are we going to protect our water resources for this and future generations within our economic possibilities? We have to develop new systems to obtain a maximum yield from the resource without restraining its future use. Now, here is a list of some of the problems for which we need to seek appropriate solutions. First, which is the best available system to treat the liquid wastes so their reuse could be feasible? At present we are still treating the wastes and discharging them into the sea.

How could we provide an adequate treatment for the sewage and solid wastes generated in our rural areas? How could we induce the recharge in our aquifers, and protect them from salt water intrusion? How can we reduce water consumption? and finally, how can we provide our rural areas with an inexpensive water supply system? Those are the most urgent problems related to our water resources that I consider should be the focal point of a research program.

COMMONWEALTH FLOOD CONTROL PROGRAMS

Eng. Juan M. Olivieri, Technical Assistant to the Secretary
Department of Transportation and Public Works
Commonwealth of Puerto Rico

Among the various responsibilities assigned to the recently created Department of Transportation and Public Works, is the Flood Control Program. It is a rather new program established in the year 1966 by the Commonwealth Planning Board.

In the year 1968 the flood control responsibility was assigned by law to the Public Works Department, and as part of this program, several flood control projects were constructed including, among others, the Yaguez and Bayamón Rivers channelizations; two storm drainage systems for Cataño, as well as several small projects throughout the island. The flood control and other purposes projects for the Portugues and Bucana Rivers are being designed as a cooperative effort with the U. S. Corps of Engineers.

The flood control program is a continuous one, funded mainly by allocations from the Commonwealth Legislature. Of course, some municipalities as well as local developers have contributed in the past with limited funds for this program.

The whole flood control program is coordinated on all phases with the Planning Board.

In addition to the construction of flood control projects, the Department of Transportation and Public Works evaluates and endorses all projects submitted for approval to the Planning Board, which are either located within the flood plains or involve the channelization of a body of water. The Department, also, evaluates the environmental impact statements of each project.

The flood control program is aimed at two main purposes.

1. To protect the life and property of a large number of residents in areas subjected to periodic flooding.

2. To reclaim floodable land for multiple purposes developments. There are in Puerto Rico approximately 300,000 acres of floodable land to different magnitudes. If we set aside 150,000 acres for agricultural purposes, there remains 150,000 acres that could be reclaimed with a present value of about \$600 million.

Earlier this morning someone made a remark of storing water to avoid its discharge into the sea through man-made channels. I would like to let you know, fellows, that when a flood problem is analyzed, the alternative of constructing a dam upstream is a standard procedure. For example, let us take the case of the Yaguez River. The first phase is already constructed. The second phase under construction includes an open channel 3.5 kms. long up to the Gandel Creek. The third phase includes a dam whose location is already approved. Another example is the Valenciano River Project where another dam is being programmed. At the Portugues and Bucana projects there are two reservoirs already approved at the Cerrillos River and at the Portugues River.

The Portugues-Bucana Project. This project has proceeded through the study stage and into advanced engineering design. The Administration in Washington requested funds to commence construction on this project last year; however, it was turned down by Congress at that time. This fiscal year, the Administration did not recommend funds to commence construction of the project. So, at this time, the future of that project is uncertain in date. We do not know at this time when the construction will start. But to give you an idea of the magnitude of the project, the total effort is valued at somewhat in excess of \$170 million of which more than 50 percent will be provided by the Corps of Engineers. It is a project that will provide very substantial flood protection for the city of Ponce, and at the same time, through the two reservoirs which will be part of the project, something like 32 million gallons per day for water supply purposes. Additionally,

Moving to studies, I would first comment on the major authorization document which we have from Congress. The 1970 Flood Control Act contains a mandate from the Congress that authorizes the Corps of Engineers to cooperate with the Commonwealth Government in working toward solutions to major water resources problems on the island. Dr. Santiago-Vázquez here was a major proponent of this authorization in 1969. Since that time, effort has been placed upon accelerating certain existing studies. For example, funds are being expended now on a feasibility study of a multi-purpose project on the Valenciano River near Juncos. This would be designed primarily to provide substantial water supply benefits and, at the same time, to provide some flooding protection downstream. Also, there would be some recreational areas around the reservoir site.

I might point out in regard to this project that it is typical of the types of challenges we will face in the future here in Puerto Rico because the economic feasibility criteria we must use constrain us from providing downstream flood protection if the benefits in a particular project do not exceed the cost. So, in such a case we must cooperate and coordinate very closely with the Department of Transportation and Public Works, the Planning Board, and other agencies to identify local capability to do some downstream flood control work if it cannot be justified as a part of a federal multi-purpose project.

Major efforts have been in process to establish a firm long-range program which will be used as a basis for future funding requests from the Congress. At this time, we are in the final stages of what I would call a highly modified framework study in which we are trying to identify, in a broad sense, the water resources problems and potential solutions to these problems island-wide. Once this is done, we intend to coordinate very closely the results with appropriate Commonwealth and Federal agencies in an attempt to determine priorities that the Commonwealth Government is placing on the resolution of these problems. With that knowledge, we can mutually determine which projects we can work on and which ones

the Commonwealth will be going themselves; that of course, will be the basis then for a long-term program.

The other major activity which is on going under this authorization is the Ponce Regional Water Resources Management Study. This is being done under the auspices of the Corps of Engineers Urban Studies Program and with the Congressional authorization which was provided by the 1970 Flood Control Act. This is a cooperative study in that a substantial amount of the input in terms of data, manipulation of data, and plan formulation will come from responsible Commonwealth agencies. The objective of this study, without going into great detail, is to assist the Commonwealth in establishing flexible long-range plans for water management within the southern region or Gran Sur. These plans will include programs for capital development, continuing planning and management. We expect that the major thrust of the study will be in the water supply area in that we expect to look at alternatives available to optimize the use and re-use of water within the study area and then to consider some sources outside of the study area, if it is necessary to do so based upon the various future projections. We would also be very concerned with the possible re-use of water which is now wasted to the sea in that area. Another factor of major concern is the development of programs for the control of major flooding problems within the area. In the context of the solutions which we might arrive at for the three major functional areas, we will look at recreation and fish and wildlife opportunities.

One important facet of the Urban Studies Program is that it is not our objective to come up with a list of projects to be done by the Federal Government, but rather a series of plans for local implementation. However, the capital improvement plans may include some projects eligible for federal funding. If a flood control project, for example, were to be recommended, and there was federal interest determined within the plan, then the resulting documents could serve as a vehicle for Congressional authorization for further design and

possible construction by the Corps of Engineers. However, probably the vast majority of the capital improvement programs will be Commonwealth financed. Of course, part of the results would be a study at the ramifications of project financing so that the impacts are well-understood by the Commonwealth decision makers.

DOMESTIC WATER-USE PROBLEMS AND RESEARCH NEEDS

Dr. Raúl Filardi, Sub-Director
Planning Area
Puerto Rico Aqueduct and Sewer Authority

The purpose of the Puerto Rico Aqueduct and Sewer Authority is to assure the inhabitants of the island adequate water supply and sewerage systems. To accomplish this objective the Authority has undertaken a series of specific activities, such as planning, design, and operation of the systems. Like other agencies, in doing its work it applies, consciously or unconsciously, a general methodology which involves the following steps:

1. Identification of the objectives.
2. Translation of these objectives into planning, design, and operational criteria.
3. The application of these criteria in the development of plans, programs, strategies, and other action alternatives.
4. Evaluation of the impact of the different alternatives.

It is in the application of such methodology when we largely face most of the problems affecting governmental activities, particularly those related to water resources. We will briefly point out the problems to which we are referring, taking the steps involved in the methodology one at a time.

The first step was the identification of the objectives. We all know that there is no clear definition of the objectives we have to satisfy with our works. This is inherent in the process. Among the sources we have for objective formulation are the Governor and Legislature, representing the people, and the members of the executive branch, such as agency directors, whose responsibility includes a clearer articulation of the objectives formulated by their superiors. The problems of this first step in our methodology revolve precisely around the definition and dissemination of those objectives. We lack mechanisms

that assure a clear explanation and definition of the objectives and even if we had them there are no real channels for their distribution and coordination among the pertinent agencies. We also lack the evaluating mechanisms that would determine the desirability and feasibility of the objectives, concurrently establishing priorities.

The second methodological step is to translate the objectives into criteria usable in the planning, design, and operation of systems. The objectives mentioned in the prior step are never clear, detailed or consistent enough to be readily translatable into criteria. Problems in this step may be classified into two types. The first, is basically the problem of coordination between agencies. Each agency develops its own explanation and definition of the objectives it recognizes and it is necessary to communicate this to other agencies in order to coordinate efforts. The second type of problem faced in this step is the development of criteria for planning, design, and operational purposes that respond to the island and its regional problems. These criteria are of such specific and detailed nature that they are part of disciplines like planning, engineering, and economics and therefore not directly evolved from the objective to criteria translation process.

The third step involves the utilization of the generated criteria for the development of alternatives. The problems related to this step are of three different types. There is the same problem of interagency coordination in terms of the distribution and feedback of information. There is also the problem of generating and utilizing criteria relevant to Puerto Rico, but at the level of sub-disciplines and techniques such as sanitary engineering and economic planning. The third type of problem is the difficulty involved in producing of the inventory type information. In respect to water resources we need information on the amount of supply, the demands for the resource, and the "best" way of distributing the resource according to the criteria and objectives afore mentioned. This latter problem has several facets, such as the difficulty of execution by one agency time constraints versus length of records needed, and

the possible inefficiency incurred in if all agencies start to collect data in an uncoordinated way.

The last step of the procedure is the evaluation of the impact of the different alternatives. This presents two basic problems. Once again we face the lack of coordination among the working agencies. The results obtained by any agency should be evaluated by other agencies and in such a way that feed-back is provided. Second, the problem involved in the generation of evaluation methods that help to identify the best alternative. The whole process could be accelerated if all the agencies involved could reach a common agreement on the methods to be used.

According to the different steps of the methodology described and discussed above, we can point out the following general research needs. First, the need to develop certain criteria relevant to Puerto Rico's conditions. As an example we can develop design criteria such as water use factors and maximum flow per hour or per day. Research could also be conducted to determine the assimilative capacity of our rivers and the feasibility and efficiency of different types of liquid waste treatment under our climatic conditions. Secondly, an inventory type analysis geared to determine the available water resources and the projected water demands should be done. One example could be a study of water use by different industries based possibly on economic growth and responding to the impact of water quality standards. Another example could be modeling of the island's groundwater resources which would enable us to predict the impact of extraction and recharge. Finally, we can point out the need to investigate different methodologies usable in the evaluation of alternatives in water resources planning and development. This would be with the aim of providing a common base for all agencies involved in water resources planning, management, and development activities.

DISCUSSION:

Dr. Antonio Santiago Vázquez - Panel Moderator

The primary purpose of this conference is to identify those areas in the field of water resources where research is immediately necessary for the solution of a given problem and in a secondary way to establish all possible links between the University and the Government, so they can work more closely toward the solution of the water resources problems. Unfortunately, we have suffered the experience in Puerto Rico in which no coordination in the research field between the University and the Government have existed at all. Thus, we must change this situation in order to obtain better efficiency by sharing the work and coordinating the research needs.

Since the objective of the Water Resources Research Institute is to help, stimulate, implement, and support research in water resources, it must take the opportunity to work in close coordination with the action agencies related with the water problems in Puerto Rico which have already feel the need of such information.

Mr. Santos Viscasillas, Soil Conservation Service, USDA

It is of primary importance that we consider the erosion and sedimentation problems occurring in those structures built for the storage of water as well as over the entire island system. There are a group of artificial lakes which were constructed years ago when the construction costs were relatively low.

Then if we can not control by any means the erosion and the amount of sediments reaching our lakes, their storage capacity shall be greatly reduced implying the construction of larger channelization works. This problem of sedimentation is not only

occurring in the lakes but also along the bed of our rivers. Thus, in my opinion a public policy directed toward land use control which helps the improvement and conservation of soils must be developed.

It is already a common thing to have an urbanizer who does not widely take into account the physical implications of his project upon the land and structures devoted to agricultural purposes which in most cases surrounds the area to be developed. Sometimes the construction of a drainage system is completed without considering the work time-life effect into the costs. In general, we can easily recognized the seriousness of the sedimentation problem upon the construction stage of structure as well as for its maintenance and time-life. Finally, having an increase in population growth, strong measures regarding land use decisions and soil conservation practices will have to be adopted.

Eng. Pedro Mora - Member, Planning Board, Commonwealth of Puerto Rico

I agree that this problem of erosion and sedimentation urges from us an effective and rapid solution. Unfortunately, today the Planning Board has no legal authority to undertake any action in rural zones. It is precisely one of the aspects we are trying to include in the new legislation to be proposed in the near future; how to control land use in rural areas.

Dr. Antonio Santiago Vázquez:

Definetely we can not have an adequate water resources development program without attaining a very complete soil conservation program. Some parts in Puerto Rico have been and/or, are still being strongly eroded; as a result the capacity of our lakes have been reduced noticeably constituting our principal problem.

Eng. Rafael Cruz Pérez , Puerto Rico Industrialists Association.

I would like to have an explanation upon the following question: If the urban development occurs in the valleys and being the lakes and other embankments constructed in the mountains, how then, material deposits can take place and affect the capacity of those reservoirs?

Dr. Antonio Santiago Vázquez:

It is true that the urban growth in our cities occurs in the coastal land but if we extend the concept of urban development to rural highway construction and any other type of development made in rural zones involving the removal of land, then we will readily have considerable amounts of sediments that can be transported either by water or wind.

Dr. Antonio Santiago Vázquez:

I am glad to let you know that actually and by the first time in this Campus, a course on ground water is being offered to the graduate students. I have the privilege of teaching this course, but only three students have been registered. Thus, to increase the registration level in the future, qualified undergraduate students can be allowed to take the course.

Question by Unidentified Person -

Does the creation of the new Department of Natural Resources imply any changes in the existing water law of Puerto Rico?

—Answer to the previous question—

The law that creates the Department of Natural Resources does not alter or change in any way the actual water law. It is only required from now on to have a license for the digging of wells. A bill on water law which that has been submitted in and discussed by the legislature in its last two sessions is now again under consideration. The main point of this bill is a demand to declare all waters in Puerto Rico of public domain.

Dr. Antonio Santiago Vázquez

We have been working in Puerto Rico under a water law which is no more than a copy of the Spanish water law of the 18th century. It is hard to think that today we are still using such obsolete principles and rules; especially when there exists today specialized administrative agencies such as the Environmental Quality Board and the Department of Natural Resources.

Hon. Cruz A. Matos, Secretary of Natural Resources, Commonwealth of Puerto Rico

In respect to septic ponds, the regulations establish that whenever a sewer line is constructed to serve a particular area, any adjacent property having a septic pond for sewage disposal must be connected to the line and the septic pond totally closed in a period of 60 days

Dr. Antonio Santiago Vázquez

The use of septic ponds or latrines in rural zones constitute a potential source of damages to water supply sources or wells near the living area, the probability of a

connection to develop between a potable water ponds and a septic ones increases as more living units are constructed in the zone. Thus, it is a problem which careful attention and control must be given.

Eng. Rafael Cruz Pérez, Puerto Rico Industrialists Association.

The Department of Health has developed techniques for the rapid and ease installation of precast latrines in rural zones. Those latrines have the advantage of working as a small local treatment plant serving a living unit, and their unit costs are in some instances lower than for a latrine constructed in situ. Therefore, if a regulation is imposed to restrain the use of latrines, then we already have an alternate mechanism at a competitive cost to provide a temporarily adequate sanitary service to a living unit.

Dr. Antonio Santiago Vázquez:

Thanks to all of you, participants and honorable audience. Now, may I take the opportunity to inform that on November of the present year the Annual Convention of the American Society of Water Resources will be celebrated by the first time in Puerto Rico. I hope you can accompany us to this conference in which I will have the privilege of being the General Chairman.

Many thanks to Dr. Roberto Vázquez for his invitation and to all distinguished directors of agencies in Puerto Rico who attend this conference.

Third Discussion Panel

"WATER FOR INDUSTRY"

Moderator:

Dr. Fred V. Soltero-Harrington, Professor
Chemistry Department
University of Puerto Rico
Mayaguez Campus

Participants:

Eng. Owen Martínez, Director
Planning Office
Puerto Rico Industrial Development Company

Eng. Hernán Rodríguez
General Manager
Irrigation Services
Puerto Rico Water Resources Authority

Eng. Rafael Cruz Pérez
Environmental Affairs Committee
Puerto Rico Industrialists Association

THIRD DISCUSSION PANEL - "WATER FOR INDUSTRY"

Dr. Fred V. Soltero Harrington
Professor, Chemistry Department,
University of Puerto Rico, Mayaguez Campus
Panel Moderator

INTRODUCTION

Before entering upon the theme of this panel discussion, which is the Industrial Use of Water, I would like to make a few personal introductory remarks. When asked to preside this activity I had some moments of hesitation. As you all know until a few months ago I held a rather high administrative position here. Since leaving that position I have rather lost the habit of making public appearances. However, given the importance and interest of our present subject, I readily accepted.

Water resources and their use in general is an area of great personal and professional interest to me. During the year 1965 I had a sabbatical leave and spent my time at the University of Wisconsin doing research and studying the chemistry of water. As an engineer, as a chemist, and as an interested citizen, the theme of this panel as applied to Puerto Rico, has the utmost urgency and interest to me and I am therefore particularly pleased to be able to participate in this activity.

Industry presents, as is well known, the most difficult problem in the field of water resources and usage. This problem is massive demand; to use a rather shocking but effective expression, "industry is a glutton with water". In Puerto Rico, due to our present industrial development, this is a real problem for us. Our thinking about water resources and their use must be oriented toward this problem. We must think and act in such a way that our industries receive the water they need to operate, but equally legitimate demands of other areas like agriculture, urban development, and all other social requirements must also be satisfied. We cannot permit an unbalanced distribution of this vital and precious resource. I believe,

therefore, that our present theme must be handled with the greatest possible attention and care, and I am confident that this is precisely the manner which our panel will employ.

Our present panel, by the way, looks like a mini-alumni meeting. Our three speakers are engineers graduated from this Institution.

Mr. Owen Martínez, our first speaker, graduated in 1948 and has worked for many years in the Planning Office of the Industrial Development Company. After finishing his studies in Chemical Engineering at this University he had further training and studies in the states and received the master degree in Planning at MIT in 1961. Owen will speak about the water needs in industrial development. Without further preliminaries, I am pleased to present Mr. Owen Martínez.

WATER RESOURCES NEEDS FOR INDUSTRIAL DEVELOPMENT

Eng. Owen Martínez, Director, Planning Office,
Puerto Rico Industrial Development Company

In our agency we have been working from a long time ago upon that matter of water resources planning because are of great importance in the set of industrial needs. Our task is to coordinate the existing available water facilities with the existing industrial needs and the water-laws which affect the establishment and operation of those industries. We think of the planning process not only as planning in long term range but the daily efforts toward the adjustment between the water needs for a particular project and the available water facilities occurring at any part of the island.

We have realized the fact that the economic needs in Puerto Rico are different from region to region and that the establishment of an industry is more desirable in some particular areas. Therefore we tend to carry industrial development to the areas of lower incomes. But in most cases, we find that where the industry is more urgently needed there does not exist the required water facilities. Our objectives are first, to get information about where the water resources are; thus an industry seeking a place for its operation could know before its establishment where the water is, under what conditions that water can be obtained, and under which standards the government would allow the use of the resources so as to consider the treatment and disposal of the liquid wastes. On the other hand, we face the need of an industrial development in the long run. We need to create employment opportunities by importing certain classes of manufacturing activities which will invariably require large amounts of water.

We know that industry requires water for different purposes, specifically for drinking, for sanitary uses, and for the cleaning of facilities. I would say according to our experience that 80% of industries uses the water for those purposes and that it is only a 20% of the total

requires very large volumes of water.

In respect to the water distribution program, we know that large quantities of water are to be found along the north coast. It is not only true for surface waters, but for the ground water as well. Thus, it represents a serious problem because of the water needs which could be generated in the southern region with the creation of new employment opportunities derived from industrial expansion.

While lacking water in the required proportions, the south coast constitutes the most attractive area for the development of harbour facilities. From the economic point of view, it is more feasible to construct harbour facilities in the south coast than in the north coast. We have a situation in which nature gives us the water along the north coast and sculpt for us potential harbour sites in the south coast. This is a task involving economic and social principles to determine both, the optimum level of development in the south coast or to allow and confine the industrial development along the north coast, in the case we decide to keep the water in the place it occurs. A specific example of the above situation is the Toa Vaca case where the advantages of transporting water from the north to the south coast have not been yet determined.

Among the most important research needs upon water resources we give special considerations to study the techniques of industrial water re-use. I assure that our agency is willing to support all the efforts needed to increase the knowledge about that important field. We are considering the possibility of substituting the water as a cooling agent or to develop new techniques in cooling processes. There is no doubt that desalinization stands in the future of Puerto Rico. Hence, we need to conduct research on desalination techniques and to determine its costs.

In respect of priorities we know that they are originated from the competition between agricultural, industrial, and domestic water uses. Suprabiological water uses by animal and plants are also under consideration. It means that nature fights with itself for water. We have to consider the following questions when it is decided to assign priorities in water uses: How are we going to use the water we have?

Do the industrial water uses represent the greater benefits for Puerto Rico? I take up the problem because in many occasions we found ourselves discussing about conveniences and importance of some particular water uses, but how important are these water uses; which is the best to meet the basic needs for Puerto Rico? We confront a situation of substantial unemployment and we recognized it as the critical point of our economy. All programs of water resources are important but it is a matter of priorities to determine the purposes and the proportion in which the available water resources will be distributed; and research must be done in this respect.

To determine the amount of ground water we have as well as its quality, constitute another research field of tremendous importance. So, there is insufficient information in this respect in Puerto Rico. Rivers and other surface bodies of water are relatively easy to measure, but still we do not know how much underground water resources we have.

WATER RESOURCES PLANNING - A POINT OF VIEW OF THE PUERTO RICO
WATER RESOURCES AUTHORITY

Eng. Hernan Rodríguez, General Manager,
Irrigation Services Division
Puerto Rico Water Resources Authority

I would like in the first place, to thank Dr. Vázquez for having invited Mr. Julio Negroni, Executive Director of the Puerto Rico Water Resources Authority, to participate in the water resource planning session being held in the Water Resources Research Institution of the Mayaguez Campus. Mr. Negroni regrets that previous unavoidable engagements prevented him from coming. He has delegated in my person to represent him here today. My name is Hernán Rodríguez; I am a Civil Engineer and the newly appointed Head of the Irrigation Services Division of the Puerto Rico Water Resources Authority.

Dr. Vázquez requested in his letter a 15-minute presentation on our experience on water resources, related problems and possible ways of solving those problems. At the risk of repeating what we might already know, let me begin by stating that each and every time we think about water resources planning and development, our main concern has to be forefold; that is, how much water is there available in the Island, how much of it can possibly be collected, how much is already being used or misused, and how the remaining usable quantity can be hindered and controlled for the benefit of our society. We think that all water resource problems arise from these four factors: availability, development, use, and potential development. So, there has to be a water budget.

Let me bring forth some facts gathered from USGS and other reports regarding our water balance. In Puerto Rico, the average annual rainfall has been estimated to be in the order of 69 inches equivalent to an annual average volume of 12,300,000 acre-feet of water. Due to the irregular rainfall distribution, with respect to time and to climatological variations

submitted to meet the island's needs.

Existing estimates place the actual use of water in Puerto Rico at the level of about 1/3 of the controllable amount, thus, leaving about 2.7 million acre-feet of potentially available water for other uses. The high cost and magnitude of the facilities developed up to the present to control the actual amount of water being used, should be beared in mind when the thinking is done for future developments. Water is a costly commodity nowadays as evidence by the following figures. The existing facilities include some 2,400 deep pumping wells. A total of 30 public dams and reservoirs have also been developed to divert, store, and regulate the runoff from about 800 square miles of watershed in the most important streams and rivers. The combined available storage capacity of those reservoirs is approximately 300,000 acre-feet.

A total of \$63 million have been invested in the hydroelectric plant in service and \$22 million in the hydraulic works of the public irrigation systems. Investment by the Puerto Rico Aqueduct & Sewer Authority already exceeds the \$400 million mark according to their 1971-72 report. These figures give us an idea of the magnitude and importance of the efforts needed in planning, developing, utilizing and maintaining our water resource systems and of what lies ahead of us with the impending demand upon water due to our economic growth and to the population increases.

The Puerto Rico Water Resources Authority was in the beginning principally a hydroelectric power enterprise. Late in the forties, the further development of hydroelectric power became uneconomical. In the past 30 years, the economic development of the Island has been of such magnitude that the yearly increment in electric demand requires large size power plants in the range of 200,000 to 450,000 kilowatt-units and over. The steam electric generation has grown to a point that it is now 99% of the total output. Increased labor costs, coupled to the fact that the best hydroelectric sites have already been developed, made the financing of new hydroelectric projects inadvisable. The remaining dam sites for hydropower development are not capable of sustaining large size power plants of the capacity needed for our present and future needs. In fact, the last hydroelectric development accomplished in the Island was the Southwestern Puerto Rico Project, built in 1955. The Authority does not envision new hydroelectric developments in the near future.

The development of the existing hydroelectric projects in Puerto Rico was brought about with the creation of the irrigation systems. Government intervention in the construction and operation of irrigation projects in the Island arose from the necessity of making fully productive certain highly fertile lands in the coastal plains that were handicapped by the lack of water. The realization of irrigation projects for the benefit of those lands could not be accomplished as a private undertaking. The reasons were the magnitude of the works and the large investment of capital that was required. Furthermore, due to the fact that the Island's surface water resources are no the most part a public property, the government has logically the only entity in a position to assume the responsibility for determining the most appropriate and beneficial use of water.

So far, there are three public irrigation systems in Puerto Rico, constructed and owned by the government. They are known as the South Coast, Isabela, and the Lajas Valley Irrigation Systems. The P.R.W.R.A. is entrusted by law with the administration, operation, and

maintenance of these three systems. The cost of operation, and maintenance of the irrigation systems is financed through irrigation taxes levied on the lands receiving the water, with the sales of water, and legislative appropriations to balance the operating budget.

The combined length of the irrigation canals in all three systems is approximately 528 kilometers. Total land area served is 62,000 acres. The water quota varies from 3 acre-feet per acre per year in the Lajas Valley to 4 acre-feet in the South Coast, and the Isabela area. The irrigation water quota is 210,000 acre-feet per year. Due to seasonal variations in rainfall and the corresponding shortages in runoff, only 140,000 acre-feet of water are delivered on the average to the lands under irrigation. During water shortages, the available water is equally distributed for each acre of land with a right to a quota. When curtailment is imposed, landowners are allowed a period of 11 months to make up for part of the water not delivered to them, provided that water becomes available at the reservoirs and is sufficient to cover first regular quota and then the shortage. If deficiencies are in excess of 25 percent in any year, the excess has to be credited by law to the farmer in his payments of the next years tax levy.

Farmers in the South Coast supplement the irrigation water with a private deep well pumping network scattered all over the coastal plain. The Puerto Rico Water Resources Authority also sells raw water to the Puerto Rico Aqueduct and Sewer Authority for the aqueducts of the municipalities of Guayama, Arroyo, Patillas, Juana Díaz, Villalba, Lajas, Aguada, Aguadilla, Isabela, Moca, Rincón and the Ramey Air Force Base. The average amount of water delivered for this purpose amounts to about 15,000 acre-feet per year.

With the exception of Guajataca Reservoir there are no excess waters available to be diverted to non-agricultural uses, besides those waters at present delivered to the above mentioned municipalities. Furthermore, the large amount of leakages and the reduced capacity of the canal system allow only small deliveries for non-agricultural uses. Guajataca Dam and

Reservoir, on the other hand, is a special case. Extensive repairs and rehabilitation measures have to be accomplished to this dam before it can fully meet the demand of water in the northeastern corner of Puerto Rico.

The Commonwealth Government is taking steps to assign \$325,000 for investigations, design, and starting the construction of improvements. We have engaged the cooperation of the U.S. Bureau of Reclamation for the planning, design, and construction of the Guajataca Dam improvements.

As for the development of new irrigation systems, we might say that water resources for irrigation in Puerto Rico have already been developed, with only one or two minor possibilities still remaining. As of now, there is a highly competitive demand for the use of water among industrial, municipal, and agricultural uses. Important deterrents to the development of future irrigation projects are the high and rising costs of construction, operation and maintenance vis-a-vis the limited repayment capacity of farmers.

WATER USE BY THE INDUSTRY - PROBLEMS, RESEARCH NEEDS

Eng. Rafael Cruz-Pérez, Environmental Affairs Committee,
Puerto Rico Industrialists Associations

A few hundred years ago, the recently founded city of San Juan having a low population density disposed its untreated liquid wastes, both sewage and rains, to the San Juan Bay without causing a considerable pollution problem. Since that time, the city of San Juan has been growing up to the point that today there are only a few square feet in the city available for development and as in the past the city continues discharging its wastes into the bay. Thus, damages have become so large that now they can not be ignored any longer. The industry confronts a similar situation in a short term range. At the beginning of 1950's, there were established in Puerto Rico the so-called heavy industries primarily concerned with manufacture activities. This type of industry has widely spreaded so fast in the last years that its growing has not been yet determined by our planners. Those industries as in the case of "centrales" and distilleries were and still are discharging their wastes into the environment because, as in many other parts of the world, we had not learned the experience of the San Juan Bay. We had not understood the importance of treating the effluents to prevent the pollution of the bodies of water to preserve them for the enjoyment and benefit of our people. This way of disposing the liquid wastes without treatment together with an increase in the water demand for domestic and industrial purposes have stressed the water problem. It has compelled the establishment of unplanned reuse and recirculation practices. There is also evidence that some towns on the island have been drinking water from a river which had been already polluted upstream by the discharge of the sewage of an upper town. The picture has not greatly changed up to now because of the belief that water being an unlimited and renewable resource, it could stand all loads discharges into them.

It is known that the character of the liquid wastes differs from some water uses to others. The water used by the industry constitutes a more dangerous pollutant to fresh waters than domestic wastes because of the presence of typical and exotic materials which are both, rarely encountered in the environment and very difficult to treat. Another important difference between industrial and municipal water uses is that the rate of water consumption by the industry is much higher than any other water use. A relevant characteristic that must be studied when analyzing industrial water consumption rate is the large range of variation on water demand from one type of industry to another. By this fact we are not allowed to make planning decisions based on industry growth projections. Moreover we have to consider all possible changes in the water flow patterns within a particular industry to attain adequate planning. However, in Puerto Rico, as in many other parts of the world, the planners still adopt the classical procedures in estimating future industrial water consumption rates. In industry we should not base our plans on total demands of water, but on the quantity that is available. It is a common practice for an industry to develop its preliminary designs in respect to the amount of water available. Working in this way, we could make very important decisions related to the recycling and desalination process, mechanical cooling devices, or any other process which enables us to reduce the amount of water required.

Another very important factor influencing planning decisions arises from the requirements imposed by local authorities in respect to the quality of discharging wastes. In the case those standards were approximately close to the quality of the source supplying water to the industry, it would be very probable that a recycle process would be adopted. However, it is necessary to point out that when it is theoretically possible to develop a closed water flow system within an industry, in most of the cases, our knowledge of the technology to remove exotic materials from our wastes is not so complete as we would desire. On the other hand, we can not develop real projections based on the results of experiments made in a laboratory with two gallons of water

for an industry which could require eight millions gallons per day. This afternoon, instead of speaking of water resources, I have spoken about contamination of water, but it is important to realize that in the industrial field, the water resource and its pollution are constituent parts of a whole that is impossible to separate.

Therefore, the industry has to know the amount of water that is available. In most cases the design can be controlled by the quantity of the resource available: However, it is impossible to reconstruct an existent industrial community when at the moment of starting its activities, there is no water available. In Puerto Rico with geographical-water resources limitations it is necessary to use all our energy and efforts and all those mechanisms and technology that will enable us to reuse the water resources at its maximum efficiency.

DISCUSSION

ces problems open-mindedly, avoiding all the prejudices against or favoring one type of solution or another, and to explore any possibility theoretically attainable, although not technologically feasible under the actual circumstances. It is one of the purposes of this conference to generate ideas which can be further analyzed on a laboratory scale, seeking new methods and procedures which could enable us to make wiser decisions about water problems. We already heard from Eng. Owen Martínez about the interest of Fomento to study new techniques in industrial water reuse. I particularly believed that there are very important possibilities which can be studied in this field of industrial reuse so that we can reduce to a minimum the amount of water polluted in industrial process now being discharged into the rivers or into the sea. Moreover, depending on the character of pollutants, previous treatment of industrial wastes can be considered to make available that water for either agricultural or human supply purposes instead of merely discharging them into a water course. Here, we have a very important field of research where this University could make important contributions.

We have also talked here about desalinization. The most common method applied in desalinization which is used almost all over the entire world involves a classical process of evaporation, condensation, and distillation. But at this moment we can count on additional

procedures based on ionic interchange and the osmosis phenomena. It is, therefore, another area where refinements in the procedures are necessary. Thus, we should conduct research to find an adequate material from which a column could be made so that when sea-water is passed through, the saline impurities could be removed to a certain degree, and the water collected at the system outlet could be used either for irrigation in agriculture or in any type of human activity, involving no risk. We could begin by testing the salt absorption properties of minerals composed primarily of calcium carbonate or any other mineral of unknown properties in this respect.

In the field of irrigation practices, particularly in the case of the sugarcane our technique is to provide water into channels, from which smaller ones will carry the water to the plants. The disadvantage of this method is clear since we have no means of knowing the amount of water being used by the cane plants during the flooding period of the farm. Hence, research must be conducted to develop and improve irrigation techniques so we can make a more efficient use of the available water resources.

In respect to industrial water uses, why do we have to use fresh water in those processes where the sea water would serve the same purpose? Costs are the reason for this situation. Wherever fresh water is available, there is no worry about the choice. But because of our physical geography, the island is bounded on all sides by the ocean waters representing an unlimited source of supply for many industrial activities that we must usefully employ. Many industries could use the sea-water either as a cooling agent or as a source to produce water vapor, if the costs resulting from primary purification were competitive with those obtained from fresh water uses. Those ideas, I think, should be considered in the design and planning stages of an industry demanding large quantities of water. It is therefore, a point to which careful attention must be given because of the unlimited availability of the sea-waters. Another idea about water vapor use is that of its condensation by means of devices using solar energy.

Finally, the erosion problem caused in first instances by urban development is another topic I want to mention today. Perhaps certain regulations could be established so that, together with the requirement of a permit to urbanize an area, the developer should submit a program to reforestate the area under construction. Legislation in this sense constitute an important step which would render multiple benefits by raising the level of environmental quality in those places where an indiscriminate land use have altered the natural ecosystems. I have brought these ideas to your consideration to serve as food for thought when selecting the most important items to conduct more appropriate research in the field of water resources

Eng. Owen Martínez, Puerto Rico Industrial Development Company

In respect to the comments I made of those projects which are still in the experimental stage, I sustain that research must continue, this is vital to the industry. Frequently, we see in the literature research results with tremendous possibilities for industrial application. But sometimes a long time passed since the work was done in the laboratory until the results are put in practice.

Dr. Ariel Lugo, Commonwealth Department of Natural Resources

Eng. Owen Martínez has asked here for the establishments of priorities in respect to water uses. He also implies that the first priority should be given to the industry, leaving the water demands of our natural ecosystems as a least priority.

I want to say that strict priorities are only set in time of crisis and I do not think the water situation in Puerto Rico demands at this moment the establishments of priorities. On the contrary, we should get busy in making estimates towards the determination of an adequate water budget for the island. This water budget should not consider any component of our economic and natural systems as more important than another, since nobody here can say with any

certainty that plants and animals are more important than industry, nor people more important than plants. We have here an island-wide system composed of urban, industrial, agricultural, and natural subsystems; each one of these is equally important for the survival of the island as we know it and each one needs the necessary amount of water for its own survival. What we need is a water budget that takes into consideration the survival of the whole island system with each one of its components having an adequate amount of water for its own survival.

There is another thing I want to talk about: the issue of employment. Generally when we are evaluating the environmental impact of a development, the need to generate employment is always brought up. Of course, nobody is or could be against the need of creating new employment opportunities, but we must also make the best use of our manpower capacity and put it to work for the benefit of society.

For example, the Department of Natural Resources has undertaken a reforestation program which will generate employment and at the same time will help to preserve our water resources. We must be aware that our island is a system whose capacity to sustain a given standard of life besides being limited by the availability of industry is also limited by its size and the variety and quantity of its natural resources. We should not think that one item is more important than another.

Eng. Owen Martínez, Puerto Rico Industrial Development Company

In general terms I agree with Dr. Lugo, hence, basically my attempt was to show the need to distribute the available water resources according to the magnitude of the demand of the various water uses in our society. It does not imply that a specific water use will tend to monopolize the totality of the resource. However, I still believe that the water situation requires the establishment of priorities. I also have a comment related with the explanation made by Eng. Cruz Pérez. It is known that the industrial water demand is part of a production

function. The production function involves technological aspects that although it has a relative degree of flexibility, it also displays a definite production capacity limit which allows certain projections. One of the main reasons why many industries are not using efficiently the water supply is because they are using water as a non-economic resource. This means that a price has not been assigned to the water, and that it is used while it is available. Instead of substituting other production items with water, it is substituted by other production items. The problem is to have a balance production function where water has its appropriate economic value.

Eng. Cruz Pérez, Puerto Rico Industrialist Association

I do not completely agree with Eng. Owen Martínez upon this matter of predicting water consumption rates for the industry because a change in the character of the industry implies another change in the amount of water supply. First of all, we cannot assure that the chemical industry will be the most important one in our future. Maybe our most important industrial activity will be the food production. If this were the situation in the near future, then the water use problems and specially the proposed alternative of recycling, water reuse, etc., would be quite different. Depending of the type of industry, we could have to supply water volume requirements ranging from 3000 gpd up to 8 mgd. Those are the differences we are taking about. Today nobody, even the owners of the industrial complexes themselves can make reliable projections upon water consumption rates within the next twenty years. Nevertheless, there are many factors that are very well known which can serve as a basis for an adequate planning of the water resources. For example, we can predict fairly accurate human water consumption, per capita consumption. If appropriate population projections are made, then we can predict the future human consumption. Besides, we can estimate the needs for an ecology balance and what is left will be available for industrial uses. This available water

will determine what type of industry should be promoted. In other words, water resources should serve as the basis for water consumption, not industry.

Agro. Santos Viscasillas, Soil Conservation Service

Regarding the water devoted to irrigation purposes, I think that most of the problem lies in the management of the available water. Field experience obtained dealing with various irrigation systems on the island has shown that although a large volume of water is in storage, it is not available at the time that it is precisely needed. I would like to suggest to Eng. Rodríguez that this situation requires an evaluation of those intermediate control lakes of the Southwest Irrigation District (Lajas Valley) and the Southeast Irrigation System (Patillas and Carite). Although sometimes, the water is available, the methods of distribution and application of irrigation waters are still the traditional ones. As a result we have the same operational water deficit due to the distribution and application inefficiency.

To avoid and prevent such problem, we have available an indefinite number of modern techniques which can be used in the field of water application and distribution as well. The best way to make the people realize this fact is by means of an educational program based on the need of making better use of this resource.

Prof. Luis A. del Valle, Faculty of Engineering, Mayaguez Campus

There is a question I would like to make and I would like to hear the points of view of both, Eng. Cruz Pérez and Eng. Owen Martínez: What do you think if the Aqueduct and Sewer Authority instead of having a falling consumption rate, eg., the more water consumed the lower the price, they would implement a rising rate? The latter implies that after a certain point as the amount of water consumption increases the price per unit volume of water also increases.

Eng. Owen Martínez, Puerto Rico Industrial Development Company

Since I have no experience related with water rates I can only give my opinion by considering its effects upon industrial development. I think that a water rate of a rising character will seriously affect industrial development, especially in situations where the industry requires considerable amounts of water.

Eng. Cruz-Pérez

In my opinion the water rates should be based only on the costs incurred to render the water service to the customer, regardless of the amount of water delivered to them. This would be the ideal situation but I can not imagine how it could be established in practice. In general, a large part of the costs involved in water services comes from the distribution system. The more water is transported, the less is the price of supply. I think that the actual water rates reveal this concept of pricing policy. In any case, I consider that the ideal water rates should only take into account the cost of carrying the water to the customer.

Dr. Soltero-Harrington

Our colleague Eng. Rodríguez has pointed out that at this moment, the production of hydroelectric power in Puerto Rico is not feasible. I would appreciate if he explain to us the reasons of this statement, particularly when we face a new rise in the prices of the Venezuelan oil.

Eng. Hernan Rodríguez, Puerto Rico Water Resources Authority

Since ninety nine percent of the total demand of electrical energy in Puerto Rico is supplied by superheated steam processes, and the cost of operation of the hydroelectric power plants have risen to such magnitude that the Water Resources Authority has been forced

to finish the operation of the latter. The case of the Guajataca Power Plant is a very clear example of this situation.

Mr. Santos Rohena, Environmental Quality Board

What does the panel think of the idea of developing an island-wide public policy in regard to water resources use similar to the one established for land use?

Eng. Hérrán Rodríguez

First I would like to take the opportunity to answer a question originally made by Mr. Viscasillas in respect to the utilization of water for irrigation purpose. I want to let it be clearly established that the responsibility of the Water Resources Authority in regard to irrigation is to deliver the irrigation waters to the highest point of the farm from which the farmer could easily distribute it to the rest of the farm. It is not our responsibility to employ any modern irrigation techniques at all. This should be done by other agencies. Of course, if this was done, it would benefit the Authority since more water would be available on drought periods.

Dr. Soltero-Harrington, Panel Moderator

Well, we have to leave Mr. Rohena's question on the table since we ran out of time and another discussion panel is waiting. If you have any other question please try to ask them to the next panel or leave them to be discussed at the end of the Conference.

Fourth Discussion Panel

" WATER AND ENVIRONMENTAL QUALITY - RESEARCH AND DEVELOPMENT "

Moderator

Dr. Robert Schneider, Water Research Scientist
Office of Water Resources Research
U. S. Department of the Interior
Washington, D. C.

Participants

Dr. David M. Grubbs, Director
Water Resources Research Institute
Virgin Islands

Mr. Santos Rohena, Associate Director
Environmental Quality Board, Commonwealth of Puerto Rico

Mr. Weems L. Clevenger, Director
Environmental Protection Agency
Field Office
San Juan, P. R.

Mr. Donald Jordan, Chief
U. S. Geological Survey
Regional Office
San Juan, P. R.

FOURTH DISCUSSION PANEL - "WATER AND ENVIRONMENTAL QUALITY -
RESEARCH AND DEVELOPMENT".

Dr. Robert Schneider, Water Research Scientist,
Office of Water Resources Research
U. S. Department of the Interior
Washington, D. C.

INTRODUCTION:

First I would like to mention that Dr. Vázquez deserves a tremendous compliment for organizing these series of panel discussions in such a very short time. I think also that it's logical that this final panel discussion be devoted to water and environmental quality, perhaps one of the most difficult areas to define.

The previous sessions on agriculture, industry, and development are all inter-related in various ways with how water research will contribute to the economic health of Puerto Rico, and how to make it possible for people to make a living. Now, environmental quality is a concept that we have heard more and more of in recent years. It is a word that means a lot of different things to different people and I think it is appropriate that we finish today's work with this session. Everything that has been said on the previous discussion has to do in one way or another with environmental quality and perhaps for this reason Dr. Vázquez thought it best that I chair this last session, since I represent the office of the Water Resources Research, an agency that covers almost all aspects of water research with its grants and contract programs. We try to do the research that the other agencies do not do or cannot do for one reason or another.

As I said before, environmental quality is a difficult word to define and it seems to crop up more and more in areas of high population density. On an island such as this, with perhaps the greatest population density in the United States, this subject is of paramount importance since the water resources are intimately involved, not only in man's survival, but in his enjoying of life and his surroundings.

The application of water resources research to this subject will challenge some of our

WATER RESOURCES IN THE VIRGIN ISLANDS

Dr. David M. Grubbs, Director
Water Resources Research Institute
Virgin Islands

The topic of environmental quality discussed earlier is of course closely related to other problems that are associated with any water-resource problem because it is quite obvious that water of quantity has no meaning without the word quality. In other words, it is useful water that is important.

Now, I want to touch upon the problems in the Virgin Islands that we have found and make a few comments that are the nature of background data.

The islands in the Virgin system, not unlike most of the Caribbean, are of volcanic origin. Two main islands, St. Thomas and St. John, are for all purposes just mountain peaks rising out of the ocean. We have no rivers, we have no available reservoir sites, we have practically no soil cover. If we had a reservoir site it probably wouldn't hold water any way. We have no ground water for all purposes. St. Croix is slightly different in that there is a thin sedimentary section in the central part of the island where there is an aquifer of some size. But this is also a problem because the water is of very poor quality, relatively speaking. The quality of the water deteriorates when the aquifer is drawn upon too much. And when too much water is withdrawn of course, the water becomes salty. We have a problem then as to what we are going to do with that water simply to make it potable. Historically, of course, in the Virgin Islands, in the past century, when the Danes were there, there was some development of ground water. But, nevertheless, catchments, roof catchments systems, were the principal sources of supply, and today this is still one of the principal sources of supply of water.

In the past, water was imported from Puerto Rico and, of course, the water supply there is not unlimited. In Virgin Islands we have gone to desalination plants; we seem to have a procedure there that when you need more water, get another plant. Well, I don't know how long this can go on. I don't know how much longer we can stand this. Of course this is just one problem, but along with that is the problem of what we do with wastes. We speak of our beautiful beaches, the estuaries, the coastline; but these things may be destroyed by the population expansion, by industry, and by tourism itself. And it isn't just the pollution of the fresh water resources that we have, but this affects the marine resources as well. The real problem in the Virgin Island readily cannot be oversimplified. It is simply one of maintaining an adequate supply of water of suitable quality within the economic means of the citizens.

The problem must be considered in terms of regional aspects of the system in which this problem is embedded. It is not susceptible of precise definition without careful analysis. The resolution of the problem in the context of our social, political, and economic means centers upon knowledge of the system and of inspiration and motivation, if you will, in the design of alternatives that may solve the problem. And, above all, I want to emphasize this: the wisdom to evaluate successfully the consequences of failure as well as those of success.

Now we are making some progress, and this concerns our supply of water as well as environmental quality. We are directing our research toward solving problems, but in the past, in the Virgin Islands--similar to the experiences in most of the states--our research has been conducted in conformity with what has been stated as the classic mechanism of unsolicited proposals. I look at the available reports, and this confirms that most of the studies have been oriented to the person interested in research and more particularly to the range of expertise of the individual researcher. Now, this is not necessarily applicable to a number of studies that have been made for specific purposes. Research has been carried out

PUERTO RICO'S WATER RESOURCES PROBLEMS AND RESEARCH NEEDS

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By

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Acting Director, WRI

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in response to requests by authorities. These people are aware of the particular problem but may be they have not determined that the research has reasonably certain prospects of resolving the problem in a timely and in an effective manner. So the net result is classic, a collection of research recommendations for which there is no plan of implementation.

We have had studies that have been done in cooperation with the U. S. Geological Survey. They are excellent pieces of work, and we can make recommendations, but they sit on a shelf gathering dust. Well, unfortunately we recognize the shortcomings of past experience and now the authorities are calling for action for research that may be applied to solving today's problems.

In the improvement of our environment, I'd like simply to say that there is not much improvement that we can identify; we have had a great deal of work. We have had problems everywhere. We have a problem of disposal with the solid wastes. We need to protect our bays and estuaries and our beaches. We need economic efficiency studies. We need internal analysis in our pricing policies.

These are social costs and these are things that have to be resolved. Along with it we must have public awareness, communication, and planning. We have to relate our water problems, our environmental problems, to our land use and possibly to the means of research if we are going to succeed.

WATER QUALITY PROBLEMS - RESEARCH NEEDS

Mr. Santos Rohena Jr., Associate Director
Environmental Quality Board
Commonwealth of Puerto Rico

The availability of adequate supplies of water, fresh or otherwise, is an easy problem area, although at times it may be extremely difficult to solve. Such an availability may significantly affect the development of agriculture, industry, power production or the growth of population centers.

Equally important, although somewhat less conspicuous, is the need to obtain and maintain a given quality for all of these waters. Some of the limitations that could arise to water quality problems could be as follows:

- 1) High sediment content could make impractical the establishment of an industry requiring large amounts of very pure water. Treatment costs are usually too high and use must be made of cleaner ground water sources which are threatened in some parts of the island.
- 2) Ground water sources can be affected by industrial discharges into injection wells or natural sink holes miles away from its deposition. Such effects and interconnections are virtually unexplored.
- 3) The establishment or expansion of a fishing industry can be adversely affected by the destruction of natural breeding areas or feeding areas caused by the presence of sediments in the water, the presence of chemicals, or a higher BOD load than is normal for such waters.
- 4) Significant costs may be incurred in trying to achieve quality standards for coastal waters in locations where high dilution potentials do not warrant the use of such methods.

There are many more concern areas that I am sure you have faced at one time or another dealing with the water quality problem, and which involve fundamental questions that cannot yet be fully answered due to insufficient knowledge in one or more fields.

Not pretending by any means to be exhaustive in this, I will now proceed to outline for you some of the work areas where there is a need for research activities to solve some basic water quality problems:

I- Baseline Studies:

A. Natural Oceanic water quality in Puerto Rico

1. Chemical contents during seasons around the island
2. Thermal properties
3. Currents near shore and up to 150 meters from the shoreline
4. Trends in the water quality baseline

B. Inland Waters:

1. Present conditions as a function of distance from source
2. Seasonal variations of salt water wedges

C. Ground Water:

1. Trends in ground water quality at various points around the island
2. Interaction between natural sink holes and ground water strata

II- Determination of Water Quality Criteria:

A. Biological Needs:

1. Which are the food webs that maintain healthy marine ecosystems around our coastal areas and within our island water bodies?

a) Which are the key elements of this food web?

b) Where are they located?

- c) How can they be affected?
 - d) How can they be protected?
2. Where are the breeding places for the various trophic levels of our various marine ecosystems?
- a) How can they be affected?
 - b) How can they be protected?
3. What elements constitute the natural habitat of a well balanced and healthy marine ecosystem? i.e: coral, mangrove, estuarine area, thalassia beds, etc.
- a) How can such habitats be protected?
 - b) What affects them?
4. Based upon the mentioned biological needs, realistic standards for water quality in Puerto Rico should be developed, covering:
- a) permissible chemical concentrations
 - b) thermal aspects
 - c) suspended solids
 - d) heavy metals concentrations

B- Industrial Needs:

1. Projections of water needs, in terms of volumes and qualities, for the industrial development.
2. Studies on optimization techniques for supplying such water needs; with necessary allowances for urban growth projections.
3. Development of necessary standards for water quality based on such expected needs.

III. Other Needs:

The development of water quality criteria that will lead towards the establishment of

realistic standards, should be carried out with additional information that may be given by studies such as the following:

A- Pollutant degradation studies:

1. Oil

- a) degradation rates in oceanic waters
- b) factors that can enhance such degradation, or hinder it
- c) effects

2. Heavy metals:

- a) main sources
- b) fate of such heavy metals once released
- c) reconcentration mechanisms
- d) effects

3. Nutrients:

- a) distribution and relative contribution from sources
- b) fate once released
- c) effects

4. Pesticides:

- a) sources
- b) fate
- c) accumulation or degradation mechanisms
- d) side effects

5. Sediments:

- a) source distribution and magnitude
- b) fate
- c) effects

6. Thermal dispersion studies and effects:

7. Other possible concern areas:

a) Acid discharges expected from mining operations

b) Other industrial discharges

B- State of the Art Studies for Pollution Control Technology Applicable to a Tropical Environment:

1. Treatment plant outfall location and degree of treatment desirable for such location.
2. Land use practices for controlling sedimentation sources.
3. Pesticide selection and desirable control
4. Waste heat utilization or dispersion technology
5. Cost-effectiveness of pollution control alternatives

EPA WATER RESOURCES PROGRAMS
FOR PUERTO RICO

Mr. Weems L. Clevenger, Director
Environmental Protection Agency Field Office
San Juan, Puerto Rico

I would like to give you this afternoon, that which the Environmental Protection Agency have studied related with the question of water, where does it come from, and how we are going to maintain its sources.

The Water Resources Planning Act in 1965, as amended in 1972, clearly define that it is the policy of Congress to encourage research, conservation, development, and utilization of water and related land resources of the United States on a comprehensive and coordinated basis by the federal government, states, localities, and private enterprise in cooperation with all affected federal agencies, states, local government, individuals, corporations, enterprises, and other concern. Congress therefore stresses the need for coordinated effort of all parties concerned with the field of water resources. In Puerto Rico this need can never be overemphasized. Local government agencies, of course you know them all, Aqueduct and Sewer Authority, the Water Resources Authority, the Environmental Quality Board, Natural Resources, Fomento, Planning Board, and such federal agencies, as the Corps of Engineers, Geological Survey, the Environmental Protection Agency, and others depends heavily on research done by themselves, in limited cases, but mostly done by universities, scientific centers, and industries throughout the nation.

The University of Puerto Rico, being the institution of higher education for the Island, has to take the leading role in water resources research in Puerto Rico, geared to the needs of Puerto Rico. Research is needed in developing new sources of water supply, new patterns of water use, to water quality information on existing water supplies both from grounds

and surface waters, effects of present and projected use patterns on the quality of water. More industrial water recycling and reuse is mostly inevitable. It is becoming the smart thing to do. Environmental standards concerning these changes of waste waters are expected to accelerate the pressure on industry to reduce multiple pollution discharge loads, and the magnitude of effluent volumes in order to minimize impacts on the environment. Waste waters reuse is therefore not only a resource conservation measure, but also a method of pollution control.

It is a step in tune with the times as well as future trends. Adequate research and development activity in this area is the key to accelerating the implementation of extensive waste water reuse systems and eventually the totally closed cycle. The latter which will result in no effluent discharge could comply with any water quality standards, now or in the future, and meet our national goals for 1985.

The Environmental Quality Board has prepared a draft of a comprehensive water quality management plan for Puerto Rico which cover exhaustively the waste water component. However, it postulates that research will be needed in exploring possible means of reuse of the waste water, that you just heard. In areas such as the water starve south of Puerto Rico, there is no doubt that reuse is coming in the near future. Are we prepared for it? Possible uses such as for agriculture, industry and ground water recharge, require different qualities of water and hence different levels of treatment. Eutrophication of our lakes post a difficult water quality problem, which has to be attacked at its source. Is it accelerated by pointed sources and agricultural runoff? If so, what are the best means of solving this problem? In the area of finding new sources of water, urban runoff cannot be overlooked. What are its possibilities and how can it be achieved? Industries certainly welcome new processes that will minimize and optimize water use within plants. Many of the federal and commonwealth agencies are in urgent need of data on environmental effects of pollutants, alternatives ways

of providing water supplies which at the same time are environmentally compatible, social and economic forces influencing water consumption, and so on. Yet, these agencies lack the personnel, the time or other resources to conduct these studies. Only the University can properly fill these gaps. It is a challenge for which the University of Puerto Rico must provide the leadership.

USGS WATER RESOURCES RESEARCH
FOR PUERTO RICO

Mr. Donald Jordan, Chief
U.S. Geological Survey
Regional Office
San Juan, Puerto Rico

The direction of water-resources investigations in Puerto Rico in the past has been one of responding to the demands for water by agriculture, public water supply, and industry. The results sought were rather simple: where is it, how much, and is the basic chemical quality within the required limits. Water resources at the time were ample to meet the immediate and projected demand of the near future. In fact, resources appeared so abundant that there was but slight concern that future demand might exceed supply. In recent years, it has been rather emphatically impressed upon us that demand can exceed supply. We have only to look at the water rationing in San Juan in the late 1960's and the almost yearly crises of water-supply problems on the south coast the past few years.

Changes are now occurring outside the immediate supply-demand picture that are affecting the direction of water-resources investigations by government, industry, and educational institutions. We are becoming increasingly concerned with the environment, in general, and pollution and conservation of resources, in particular.

Water, fortunately, is a renewable natural resource but it can be polluted or wasted through misuse. Herein lies the role of future investigations--how best to protect and conserve, but also make maximum use of our water resources. Investigations, therefore, will be directed to providing the base for management decisions in the control and regulation of water resources.

Many of the present studies by the USGS in Puerto Rico are already reflecting the trend to providing data for management decisions. An electric analog model has recently

been constructed for the south coast alluvium-limestone aquifer and a similar model for the north coast limestone is in the planning stages. Digital models have been constructed for two smaller ground-water studies--the Maunabo Valley in southeast Puerto Rico and the Lajas Valley in the southwest. These models will not die with the projects, but with revision as new data are available can be viable tools for management decisions.

A water-resources planning model for Puerto Rico has also been developed. It is basically an econometric model, designed to present the various economic alternatives of the transfer of water resources from water-rich to water-poor areas.

In the field of water quality there are projects under way in the San Juan Lagoon system and Lago Loíza. The hydraulics of water movement in the project areas are also being studied. The streams of Puerto Rico are being sampled at regular intervals for general chemical quality and indicators of pollution.

For several years the quality and quantity of streamflow in the proposed Utuado copper-mining area have been monitored to provide base-line data in anticipation of mining operations.

A study of the relation of urbanization and the intensity of rainfall to storm runoff has been under way for several years on the Río Piedras basin in the San Juan metropolitan area.

Just completed in the San Juan area is a project on the availability of ground water--an important source of water to the metropolitan area in times of drought or perhaps on some other emergency.

The mapping of historical floods in the major river basins of the island is nearly complete. Much more could be done in this field. We now know what has happened in the past, but with constant change in the flood plains we need to be able to predict what will happen in the future.

A major part of our effort is directed to the collection of basic hydrologic data; surface water, ground water, and quality of water, and the publication of these data. In addition, there is continuing effort to analyze the assembled data to reduce them to more usable form.

The trend of investigations is toward environmental hydrology with the ultimate aim of providing data and analyses usable in water-resources management. Future projects will become fewer in number but more complex in nature. In general, entire systems will be investigated rather than parts of systems. But at the same time there likely will be intensive special-purpose studies of selected aspects of water resources. The latter perhaps would be the role best suited to educational institutions. Major emphasis will be placed on water quality. Modeling will be an integral part of every project.

The future of water-resources investigation will be exciting. The conservation, protection, and use of our water resources, however, will be accomplished only by constant feedback and cooperation between the investigator, the manager, and the user.

DISCUSSION:

Dr. Eduardo Aguilar, Professor, Geology Department, University of Puerto Rico,
Mayaguez Campus.

In a way a challenge for us has been thrown to the floor about what the research needs are and how the University should get involved in that. Now, something like an answer to that:

I would like to throw also the challenge to the government and I think is just about time that enough cooperation be solicited among the various governmental agencies. So as to create what I call, maybe, environmental planning which I see is the basis for all these problems.

We see for example the Planning Board putting up every other day what they call the Master Plan, which to me is nothing more than master's theory and in most cases a master failure. That is why I just want to ask the Government, invite the Government, to pick up this challenge and go ahead and try to find adequate cooperation among the various agencies. Data exists that is going to be needed. Let's get together and put it together. We know that a chain is as strong as one of its weakest joints, and so is the environment. Let's determine the weakest ecological aspects of a region and in that way, we can plan for that region in a qualified way.

Dr. Schneider's Comments:

I might say that even though what you suggest is not the primary purpose of this meeting, nevertheless it is obvious that the meeting could serve, I think, to bring a number of government agencies together and, perhaps, open their eyes as to what the others have been doing. The primary purpose, just to recapitulate for a moment, is to bring Government, the University, and the private sector together to assure that the University, in particular, can

become attuned to the needs of the people by applying its research to the people's problems. I am sure that if additional meetings are held in the future, they will also serve the purpose that you mentioned and, of course, there are many other means by which the government agencies can compare programs and improve cooperation.

LTC. James Scott - U. S. Corps of Engineers:

I would like to underscore what Dr. Aguilar said, I think to the extent that.... well, to a larger extent, the Government is responsible for trying to initiate coordination such as we are seeing here today, and I would like to congratulate the University and particularly Dr. Vázquez for the outstanding job that he has done and the University has done in hosting this group today. I think that many of us in Government are very well aware that the coordination is not where it should be. Is only so much time that can be spend on this and we find ourselves... I think that I probably should speak for Mr. Jordan, Mr. Clevenger, we find ourselves probably spending 50% of our time, at least, talking to our counter-parts and talking to people who have some input into the program.

So, anything that can be done to improve this coordination, all of us would like to see done. I would ask the University people who are here if there are any ways that you can think out to improve this coordination process or if you can help us in any way, we would be happy to have these input, because it is a problem, we know that.

CLOSING REMARKS: Dr. Roberto Vázquez

Well, I don't think I am going to take too much time. It is already late in the afternoon and some of you have to take the plane back to San Juan. It is a pleasure to say that the work of today has been quite a success. I think we have still a lot of problems to look at mostly in planning, water resources development, recycling, etc. Although we have discussed, as some people said the problems of eight years ago, I think we are probably discussing the problems of the same nature, but more complex ones. We have realized that probably with the research that has been done according to what we have discussed here today, and we have gathered here most of the best talented persons working with our water resources problems; still, we don't have the information to solve our water problems. So, that means that still we have a long way to go, and that is something that really was our aim today, to have action. That is something that I really like, not just to have another meeting and just hear wonderful discussions, but action, what we should do and this is why we are coming up with those workshops that we talked about earlier this morning. We now need your participation to look at all those problems that have been presented today, and probably some other problems. Identify those problems and the research needs, set the priorities, and make a program, and then look for persons or institutions to do the research, and look for the funds to have it done. That is the action that I expect from this meeting and from the subsequent workshops to follow in the future.

Really I appreciate the time given by all of you that have come from San Juan, and even from Washington. We have many people here and, really, it has been a pleasure to have all of you; and I really thank you for your participation. I am looking forward to work with you on these programs that we really need, and which we will work upon.

Also I thank the University officials for their cooperation in sponsoring this conference. Thanks, to my staff and all of you who have the patience to be here up to five o'clock today. Thank you.

APPENDIX

LIST OF CONFERENCE ATTENDEES

- | | |
|---------------------------------|--|
| 1- Dr. José Joaquín Rivera | Assistant Secretary, for Planning and Programming, Department of Housing, Commonwealth of Puerto Rico |
| 2- Prof. Salvador E. Alemañy | Dean, College of Agricultural Sciences, UPR., Mayaguez Campus |
| 3- Agro. Ismael Ramírez Murphy | Executive Secretary, Agricultural Council, Commonwealth of Puerto Rico |
| 4- Eng. Pedro Catoni | Staff Engineer, Soil Conservation Service, USDA |
| 5- Mr. Joselo Sánchez | Assistant Executive Director, Sugar Corporation, Commonwealth of Puerto Rico |
| 6- Dr. Antonio Santiago Vázquez | Professor, Department of Civil Engineering, UPR., Mayaguez Campus |
| 7- Hon. Cruz A. Matos | Secretary, Natural Resources Department, Commonwealth of Puerto Rico |
| 8- Eng. Pedro Mora | Associate Member, Planning Board, Commonwealth of Puerto Rico |
| 9- Eng. Juan M. Olivieri | Assistant to the Secretary, Department of Transportation and Public Works, Commonwealth of Puerto Rico |
| 10- LTC. James M. Scott | Chief, Corps of Engineers, San Juan Office |
| 11- Dr. Raúl Filardi | Sub-director, Planning Area, Puerto Rico Aqueduct and Sewer Authority |
| 12- Dr. Fred V. Soltero | Professor, Chemistry Department, UPR., Mayaguez Campus |
| 13- Eng. Owen Martínez | Director, Planning Office, Industrial Development Company |
| 14- Eng. Hernán Rodríguez | Director, Irrigation Services, Puerto Rico Water Resources Authority |

- 15- Eng. Rafael Cruz Pérez
Environmental Affairs Committee,
Puerto Rico Industrialists Association
- 16- Mr. Santos Rohena
Associate Executive Director, Environmental
Quality Board, Commonwealth of Puerto Rico
- 17- Dr. Robert Schneider
Water Research Scientist, Office of Water
Resources Research, Department of the
Interior, Washington, D. C.
- 18- Mr. Weems L. Clevenger
Director, Environmental Protection Agency,
San Juan Office
- 19- Mr. Donald Jordan
Chief, U. S. Geological Survey, San Juan
Office
- 20- Dr. David M. Grubbs
Director, Water Resources Research Institute,
V.I.
- 21- Prof. Luis A. Rodríguez
Acting Chancellor, UPR., Mayaguez Campus
- 22- Dr. Thomas R. Tosteson
Professor, Department of Marine Sciences,
UPR., Mayaguez Campus
- 23- Dr. Francisco A. Pagán
Acting Director, Department of Marine
Sciences, UPR., Mayaguez Campus
- 24- Prof. Iván Emmanuelli
Professor, Department of Civil Engineering,
UPR., Mayaguez Campus
- 25- Dr. Ernest H. Williams, Jr.
Dept. Fisheries & Allied Agriculture,
Auburn University
- 26- Agro. Santos Viscasillas
Soil Conservationist, Soil Conservation
Service, USDA
- 27- Dr. Willie Ocasio Cabañas
Dean, College of Arts and Sciences, UPR.,
Mayaguez Campus
- 28- Mr. Miguel A. López
Hydrologist, U. S. Geological Survey,
San Juan
- 29- Mr. Vito J. Latkovich
Assistant Chief, Caribbean District, WRD.
U. S. Geological Survey, San Juan
- 30- Dr. Ariel Lugo
Assistant Secretary, Department of Natural
Resources

- 31- Dr. Ning-Hsi Tang
Professor, Department of Civil Engineering,
UPR., Mayaguez Campus
- 32- Dr. Eduardo Aguilar
Director, Department of Geology, UPR.,
Mayaguez Campus
- 33- Mr. Kenneth Finch
Director, Planning Office, Corps of
Engineers, San Juan
- 34- Dr. Roberto Vázquez
Acting Director, Water Resources Research
Institute, UPR., Mayaguez Campus
- 35- Mr. Eliodoro Rávalo
Professor, Department of Agricultural
Engineering, UPR., Mayaguez Campus
- 36- Prof. Bartolo Toro
Professor, Department of Civil Engineering,
UPR., Mayaguez Campus
- 37- Mr. Rigoberto Martínez
College of Agricultural Sciences, UPR.,
Mayaguez Campus
- 38- Eng. René Batista
Department of Transportation and Public
Works, Commonwealth of Puerto Rico
- 39- Eng. Manuel Seoane
Engineer-Planner, Department of Housing,
Commonwealth of Puerto Rico
- 40- Mr. José C. Pesquera
Soil Conservation Districts, Utuado, Puerto Rico
- 41- Mr. Carlos R. Guerra
Industrial Laboratory, Economic Develop-
ment Administration, San Juan
- 42- Mr. José A. Martínez
Assistant to the Secretary, Department of
Natural Resources, Commonwealth of
Puerto Rico
- 43- Mr. Carlos Calontiel
UPR., Mayaguez Campus
- 44- Dr. Emilio M. Colón
Professor, Department of Civil Engineering,
UPR., Mayaguez Campus
- 45- Mr. Osvaldo Torres Soto
UPR., Mayaguez Campus
- 46- Dr. Alfredo González Martínez
Professor, Department of Economics, UPR.,
Mayaguez Campus

47- Mr. Rafael Caraballo

Administrative Assistant, Water Resources
Research Institute

48- Mr. Miguel A. Vargas

Water Resources Research Institute

49- Mr. Otto Figueroa Bayrón

Water Resources Research Institute

50- Mrs. Sylvia Umpierre de Correa

Water Resources Research Institute