"CEER-T. METHODOLOGIES AND INSTRUMENTS

INTRODUCTION

The Center for Energy and Environment Research of the University of Puerto Rico is pleased to publish the partial results of an intensive, ongoing research effort being carried out by a group of distinguished scientists in a variety of fields in the Espiritu Santo River Basin in Rio Grande.

As a result of the rapid industrialization process and socioeconomic growth that has taken place in Puerto Rico over the last three decades, the study area has been subject to substantial ecological stress. This situation continues at an accelerated rate today, since the river basin and its surrounding area contain features that make it attractive for development purposes. It is of the utmost importance, therefore, that the wealth of data and information regarding the river basin's ecosystem already compiled and analyzed by the CEER researchers be made available to policymakers, so that future development can be carried out with a minimum of damage to this delicate ecosystem.

The CEER's Terrestrial Ecology Program has a long history. It was initiated in 1968 with a series of studies on the tropical forest ecosystem, co-sponsored by the U.S. Forest Service and the Atomic Energy Commission, on a 160-acre tract of land on the northwestern slopes of the Luquillo mountains. In 1976, the focus of the research effort was shifted from a forest-oriented program to one centered in a drainage basin, with a view toward providing data necessary for planning and optimum resources management at the river basin level. The Espiritu Santo River Basin in Rio Grande was selected as the study site.

Two years later, the Graduate School of Planning of the University of Puerto Rico was invited to join the research effort. The GSP began its analysis of the project with a series of questions: 1) what are the methodologies involved in the planning process, 2) what is the product of the research project, 3) who are its clients, 4) what timetable has been established, and 5)"

Is river basin planning possible in Puerto Rico, and if so, what are its potentials, levels, and constraints? The GSP determined that the principal client of the research project is the public sector, and its product is the basic data and information necessary for a rational formulation and evaluation of public policy in the river basin area. It was further determined that in view of the rapid socioeconomic development taking place in the river basin, it is of vital importance to make available, on an ongoing basis, these data and information so that policy decisions affecting the river basin will be guided by the research findings. At the same time, the scientists and technicians engaged in the research project should be aware of the nature of planning—that it is a process rather than a document, and this process should begin immediately and be carried out concomitantly with the research effort.

In addition, the GSP produced a theoretical analysis of the possibilities and constraints on comprehensive planning at the river basin level in Puerto Rico, to provide the CEER with the guidelines necessary to achieve its goal of gearing its research effort toward a more rational management of the natural resources in the Repiitu Santo River Basin. This interdisciplinary effort provided the framework for a more meaningful exchange between the natural scientists conducting the research project and the clients of that research effort, culminating in the Seminar on River

Basin Planning: Methodologies and Instruments, held by the CEBR and the GSP in September, 1978.

At this seminar, a group of policymakers from both the public and private sectors was invited to participate in an interchange of information and ideas with the scientists of the CEER and the planners of the GSP. The initial results of this effort were extremely positive. On the one hand, the policymakers were introduced to a wealth of information valuable for the management, development, and conservation of the natural resources in the river basin.

The Repititu Santo River Basin. They were also provided with a detailed theoretical framework on river basin planning, enabling them to incorporate the data and information provided by the CEER researchers into the formulation of policy decisions affecting the river basin. Perhaps even more important, the beginning of a continuing dialogue was established between the policy-makers and the CEER that should facilitate achieving the goal of incorporating future policy decisions into the results of the CEER research effort. This publication consists of the papers presented at that seminar by members of the Center for Energy and Environment Research and the Graduate School of Planning.

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A BRIEF HISTORY OF THE TERRESTRIAL ECOLOGY PROGRAM BY RICHARD G. CLEMENTS, Ph.D.

The Terrestrial Ecology Program was initiated in 1963 with a series of studies on the tropical forest ecosystem. Through a

A cooperative agreement between the U.S. Forest Service and the Atomic Energy Commission resulted in a 160-acre tract of land on the northwestern slopes of the Luquillo Mountains in eastern

Puerto Rico being set aside as a research area. The mission of the program was threefold:

1) To study the effects of gamma radiation on the tropical forest ecosystem,
2) To study the cycling of stable and radioactive isotopes through and within the ecosystem,
3) To study the base biological functions of this system such as respiration, transpiration, and photosynthesis.

Approximately 18 months of pre-irradiation measurements were carried out to characterize the forest prior to imposing the irradiation treatment. In January 1965, a section of the forest was subjected to gamma radiation from a 10,000 Curie Cesium source for a period of 90 days, followed by removal of the source. Intensive post-irradiation studies and measurements were conducted through 1966. The results of this phase of the program were published by Dr. H. T. Odum in 1970. The study of succession in the irradiated area is still under observation today.

Beginning in 1966, studies were initiated on the cycling of both stable and radioactive isotopes in the rainforest system. Since 1969, increased emphasis has been placed on the hydrological cycle from a quantitative and chemical standpoint. In 1972, Odum organized a meeting in Gainesville, Florida, for the purpose of preparing a proposal for a Tropical Biome Study to be submitted to the National Science Foundation. This study would have become part of the United States effort in the International Biological Program. The staff of the Terrestrial Program prepared a sub-unit of the main proposal, entitled "An Integrated Watershed Study". The main proposal did not prosper due to a lack of funds.

The proposal was rewritten and submitted to the Atomic Energy Commission in Washington, D.C., with a request that the Terrestrial Program be permitted to change its mission from forest-oriented research to that of a drainage basin.

This plan was approved in February 1975, and we proceeded to develop a five-year research plan. The rationale for the basin study was based upon the Island’s rapid development, which was, and continues to, accentuate the conflict between man and environment. In view of the rapidly changing socioeconomic conditions and the natural resource limitations, the decision-making process requires input data from three areas: the physical, biological, and cultural. While many isolated, ecologically-oriented studies have been conducted in tropical environments, few, if any, provided the database for optimal environmental management.

Thus, with approximately 12 years of research in the Luquillo Forest area, the drainage basin was selected as the unifying concept to provide baseline ecological data for environmental assessment at the local and regional levels.

Each drainage basin can be considered a separate entity with its own ratio of land devoted to forests, agriculture, industry, and housing. Major shifts in the land use apportioned to each of these sectors will affect the quantity and quality of water available. These in turn will determine the potential expansion of agriculture, industry, and housing in the drainage basin.

In the planning of the Program, we recognized the following general research areas:

1. Climatology

2. Hydrology
3. Land Use
4. Soils
5. Socio-Economic Analysis
6. Plant Ecology
7. Animal Biology
8. Limnology
9. Planning
10. Modelling

Review papers were prepared on the first seven areas in which two questions were asked: 1) what background data or information was available and 2) based upon the information available, what additional studies need to be done.

We found that in many cases, the databases were insufficient or non-existent. Thus, it was necessary to begin with some very basic surveys and characterization studies. The general and specific objectives of our initial effort, which we are in the process of completing now, are shown in Figure 1.

Figure 1: Goals and...

Objectives of the Drainage Basin Project

General Objectives:

Specific Objectives:
* To assess, collate, and evaluate available hydrological data and identify...

I would like to set the stage with two examples to think about. The first is taken from the Foreword of the Club of Rome report on the "Limits to Growth". The intent of the project is to examine the complex problems troubling individuals of all nations; poverty amidst plenty, degradation of the environment, loss of faith in institutions, uncontrolled urban spread, rejection of traditional values, and inflation among other economic disruptions. These seemingly divergent parts of the "world problem" have three characteristics in common:
1. They occur to some degree in all societies
2. They contain technical, social, economic and political elements
3. They interact

It is the predicament of mankind that man can perceive the problem yet, despite his considerable knowledge and skills, he does not understand the origins, significance, and interrelationships of its many components and thus is unable to devise effective responses. The failure occurs largely because we continue to examine single items in the "problem" without understanding that the whole is more than the sum of its parts. A change in one element means change in the others.

The second example deals with the problem of exponential growth. While we understand the problems involved in systems that exhibit exponential increases, there seems to be a paradox. While we recognize its impact, our reaction time in real life is too slow. To illustrate, I want to use two examples, one from the Club of Rome Report and one from real life.

The first involves the French riddle of the lily plant cited in the report. "Suppose you own a pond on which a water lily is growing. The lily plant doubles in size each day. If it were allowed to grow unchecked, it would completely cover the pond in 30 days, choking off the other forms of life in the water. For...

For a long time, the lily plant seems small, and so you decide not to worry about cutting it back until it covers half the pond. What day will that be? Of course, it will be the 29th day. You have one day left to save the pond. In real life, the growth of the Municipality of Rio Grande is following the classical example of exponential increase, as shown in Figure 2. In populations exhibiting exponential growth, many related factors tend to exhibit the same growth pattern; i.e., sewage production, solid waste production, land required for disposal of solid wastes, pollution, water consumption, demands on natural resources, etc. Coincidental with this conference, a new project that will eventually result in 2,500 additional homes was announced in today's papers. There is currently an urbanization under construction in the area with a projected total of 2,500 units. If we figure an average of four people per unit, the estimated increase in population would be on the order of 20,000 persons. The current population of the Municipality of Rio Grande is approximately 27,000, which means that we can anticipate an almost doubling of the present population with the completion of these two projects. The question in view of such a situation is: Do we wait until the "29th day", or do we begin now?

Figure: Growth of the Municipality of Rio Grande (in thousands)
Population Years

References Cited:
Meadows, D.G., D. Meadows, J. Randers, W.W. Behress II, 1972. The Limits to Growth, Universe Books, New York.
Odum, H.T., 1970, A Tropical Rain Forest. A Study of Irradiation and Ecology at El Verde, Puerto Rico Division of Technical Information, U.S, Atomic Energy Commission. Approx. 1600 pages.

PHYSICAL AND ECOLOGICAL ASPECTS OF THE ESPIRITU SANTO DRAINAGE BASIN BY RICHARD G. CLEMENTS

GENERAL DESCRIPTION:

The Espíritu Santo Drainage Basin drains the northwestern slopes of the Luquillo mountains and flows northward into the Atlantic Ocean (See Figure 1.)

The drainage basin presents a diversity of ecosystems for its small size. The upper ridges of the basin, from a 200m elevation upward, are occupied by a relatively undisturbed forest. Within the forested area, four distinct types are recognized: the Dwarf Cox Mossy forest, the Palm forest, the Colorado forest, and the Tabonuco forest. Between the forest boundary and the coastal plain is a zone that includes rural settlements, pasture, and cultivated lands. This might be called a transitional forest belt between 100m and 200m elevation.

The coastal plain area embraces pasture land, sugar cane fields, plantain and banana farms, and a coconut plantation. Included in this region is the estuary, which is bounded by excellent stands of mangrove communities of Rhizophora mangle, Laguncularia racemosa, and Avicenna nitida Jacq. The immediate offshore area includes a fringing of coral reefs and beds of turtle grass (Thalassia testudinum).

The Espiritu Santo River originates in the Dwarf Forest at an elevation of approximately 1,000m and falls to sea level over a distance of about 20km. Its drainage area is approximately 21 square kilometers. The three main tributaries of concern are the Quebradas Sonadora, Grande, and Jiménez. Some of the characteristics of the system are shown in Table 1.

Table 1: Characteristics of the Espiritu Santo Basin
Str Length __Ave.Grade Drainage
Mei Ke M7100 M
Area Km^2
Espiritu Santo 195 51 206
1000 M to 50 M elevation 89 108
50 M to Sea level 106 oat
Tributaries
Quebrada Sonadora 88 210 15
Quebrada Grande 64 136 19
Quebrada Jiménez 15 26 39

BIOLOGICAL PHASES OF THE BASIN

The drainage basin may be subdivided into three major divisions based upon major vegetation and slope: upper, middle and lower divisions. Each division has its terrestrial, aquatic and terrestrial-aquatic interface systems along with a recognizable flora and fauna.

UPPER BASIN

In the Espiritu Santo River, a sharp faunal break occurs at approximately 200m elevation due to a

This text describes a series of high waterfalls, marking the upper limit of distribution for several species of fish, all species of aquatic molluscs, and possibly many other aquatic organisms. The break in the terrestrial system is less sharp, but is associated with the boundary of the national forest at approximately 100m elevation. Even though relatively undisturbed, the forest zone between 100m and 200m may be considered transitional and as the upper limit of the middle division.

The terrestrial system of the upper watershed has been extensively studied as part of the ongoing Terrestrial Ecology Program of the Puerto Rico Nuclear Center during the 1960s. These studies resulted in descriptions of the flora and fauna with keys and checklists, measurements of isotope cycles and food webs, and evaluation of stress effects on the tropical forest by gamma radiation and mechanical defoliation (Odum, 1970).

The interface systems encompass the network of feeder brooks within the forest, most of which have alternating stretches of surface and subterranean water flow. They are characterized principally by their lack of solar input, due to shading by the forest, and also by highly specialized saprovore and detritivore biotas. These biotas include bacteria, aquatic fungi, numerous insects (mostly larvae), species of filter-feeding shrimp and the crab Epilobocera sinuatifrons as the apparent top carnivore. Algae and fishes are absent or rare in these streams.

The aquatic system is the main river channel and the channels of the three major tributaries that flow through the forest. It is characterized by continuously flowing water with a well-developed autotrophic flora. The effect of man’s actions on the lower reaches of this system is visible in the form of increased siltation, introduction of detergents and sewage, and the harvest of edible wild animals. The biota and food web relationships of the aquatic system have received little attention in past studies and are poorly understood. Current research in this area has focused...

The cycling of chemical elements within and throughout the compartments of the forest ecosystem is discussed in this section.

The middle division's human usage primarily consists of residence, agriculture, and recreation. The agricultural land is primarily used for pasture and fruit trees. Residential homes are dispersed widely, and only recently has a small urbanization project been introduced. Few industrial sources of pollution are present, as light industry is the only type currently or anticipated to be in the area.

Contrary to the upper watershed, less is known about the flora and the terrestrial system in this zone. Part of the work effort in this area has been to describe the ecosystems, including the forested areas, pastures, and croplands. In the future, hydrological and chemical inputs and outputs will be compared to those of the upper and lower watersheds.

The interface system primarily consists of intermittent streams that drain the pasture lands. Again, little is known about the hydrology and chemistry of these streams and their output to the aquatic system. The aquatic biota are mostly native to Puerto Rico. However, the African snail Biomphalaria, an introduced species, has had a significant effect as it is a vector for Schistosomiasis.

The flat lowlands of the coastal plain extend landward for approximately 5 km. Río Grande, the major town, is located on the coastal plain about 0.5 km west of the Espiritu Santo River. The terrestrial system was once dominated by sugarcane but is now almost equally occupied by sugarcane, pasture, and coconuts. Rhizophora mangle flanks both sides of the river from the coastline inland for approximately 2 km. Well-established stands of Lagunculera racemosa are found behind the red mangrove. To the east of the river, extensive areas of mangrove include the red, white, and black mangroves. Due to the low elevation of the coastal plain, drainage is necessary for crop production.

The interface system is comprised of both natural and man-made drainage ways, about which little is known. The flora and

Fauna have not been described. Little is known of the aquatic system of this estuary. Residents of the area state that the river is rich in fish life, including red snapper, tarpon, barracuda, and snook. Water hyacinths have invaded the estuarine waters but appear to be controlled by periodic flooding. Saltwater intrusion 3 to 4 kms inland has been confirmed by chemical analysis. Pollutants are evident, but studies have not been conducted to establish the degree of pollution and its effect on the flora and fauna.

The mouth of the river and freshwater-saltwater mixing zone are protected from easterly currents by a promontory that extends seaward approximately 2 kms. The promontory and river mouth are further protected by a fringing coral reef that lies parallel to the coastline (100-200 m offshore).

Reference: Odum, H. T., 1970. A Tropical Rain Forest, Division of Technical Information, U.S. Atomic Energy Commission. TID-24270 (PRNC-188).

PHYSICAL, HISTORICAL, AND SOCIOECONOMICAL CHARACTERISTICS OF THE MUNICIPALITY OF RIO GRANDE BY JOSE A. FERNANDEZ

(Note: Fermin was a student at the Graduate School of Planning of the University of Puerto Rico at the time this planning was held. He conducted research under the supervision of Dr. Helen Lips Puma and created the following piece.)

The municipality of Rio Grande is located in the northeast part of the island, bounded on the west by Canévanas, on the south by Las Piedras and Naguabo, on the east by Luquillo and Fajardo, and on the north by the Atlantic Ocean. It has a total land area of 60.8 square miles, or about 40,000 acres. The urban center of Rio Grande is only 20 miles from the center of San Juan. The municipality is comprised of the town of Rio Grande and eight barrios: Ciénaga Arriba, Ciénaga Baja, Guzmán Arriba, Herrera, Jiménez, Mameyes II and Zara. It is largely rural, with the town itself covering only .20 square miles. Barrio Jiménez, covering 12.03 square miles, is the largest barrio and Herrera, 8.25 square miles, is the second largest.

Square mile is the smallest physical characteristic. The coastal plain consists of low-lying land with marshy areas, especially in the central, western, and northwestern parts of the municipality. The southeastern part of the coastal plain is characterized by semi-flat to rolling land, with elevations ranging from 80 to 410 feet above sea level. Topography in the hill region varies from rolling to moderately steep, with elevations averaging about 250 feet above sea level throughout the entire municipality.

The most rugged terrain lies in the east-central sector, the site of El Yunque, one of the Island's highest mountains with an elevation of 8,496 feet above sea level. A total of 56 per cent of the Sierra de Luquillo range lies within Rio Grande's municipal limits.

Agricultural land within the municipality includes some 26 different types of soil. The deep soils at the summit, with gradients of 26 to 40 per cent and characterized by moderate to very severe erosion, are found throughout nearly the entire Sierra Luquillo range, as well as in small areas in the hill region. These soils cover nearly 20,000 acres and are made up of the Guineos, Macara, and Catalina varieties.

In the hill area, the predominant soils are medium deep, hard at the summit, with gradients ranging from 16 to 35 per cent and moderate to severe erosion, characteristics of the Macara variety. These lands make up a considerable area of the southeastern part of the coastal plan.

Among other soil types of some importance in the municipality is the Coloso variety, a humid, alluvial soil found in some 2,000 acres in the south-central part of the coastal plain and in small areas in the southwestern and eastern parts of the municipality. Another 2,000 acres is made up of the Salador type, acid or alkaline soils with some areas affected by salt but highly productive when reclaimed.

The Cataño and Corcoga type, calcareous coastal soil, cover most of 1,400 acres, while the Martin Peds type, a humid, lightly acid organic soil... (text continues).

The area that requires drainage makes up a little more than 2,000 acres. Year-round temperatures vary from an average of 74°F in the inland mountainous area to 76°F on the coast. The mountainous region in the southern part of the municipality lies within the area of highest precipitation on the Island. Generally, temperatures begin rising in March, reaching a maximum of 80°F during July and August, and drop again in September, falling below 74°F during January and February. Four large rivers run through the municipality: the Herrera, the Rio Grande, the Espiritu Santo, and the Mameyes, or Tabonuco. There is also a smaller river in the barrio Mameyes known as the Tabonuco. The municipality also has some 12 streams, several springs, and other small bodies of running water. In addition, there are some 1,671 acres of mangrove forests in Rio Grande. The Espiritu Santo River mangrove, which borders the river basin at its mouth, has been declared an area of public interest by the Planning Board. According to the Scientific Inventory of Land Use published in 1972 by the Natural Resources Department, the municipality of Rio Grande is made up of a total of 40,021.26 acres, of which 85.87 percent is dedicated to agriculture (see Table 1 for a breakdown of land use in the municipality).

Table 1: General Land Use in the Municipality of Rio Grande

- Agriculture: 14,158.78 acres (35.37%)
- Forests: 20,637.60 acres (51.87%)
- Water: 108.67 acres (0.28%)
- Reservoirs: 218.18 acres (0.54%)
- Marshes: 2,130.92 acres (5.32%)
- Urban: 3,018.80 acres (7.54%)
- Rural: 1,148.06 acres (2.87%)
- Public: 112.68 acres (0.28%)
- Industrial: 15.68 acres (0.04%)
- Recreation: 2 acres (0.005%)
- Commercial: 87.18 acres (0.22%)
- Non-Productive: 107.50 acres (0.27%)
- Communications: 1.37 acres (0.003%)
- Water Transportation: 18 acres (0.045%)

Of the land dedicated to agriculture, pastureland accounts for the major portion with 12,041.99 acres. An additional 1,076.91 acres are planted in coconut groves. Sugar cane, which played a major role in the municipality's economy until the mid-1980s, was no longer being cultivated by 1974, according to the Agricultural Census of that year.

The reasons for the disappearance of this agricultural sector will be explored below.

ECONOMIC ACTIVITY: Agriculture

This sector has continued to be Rio Grande's major economic activity since the municipality was founded in 1840. By 1897, Rio Grande had a total of 28,561 acres dedicated to agriculture, chiefly sugar cane and pastureland. Agriculture's share in the municipality's economy has been on the decline, however, following the period 1940-64, when sugar cane was its mainstay. (See Table 2)

As early as the 1960s, the Agricultural Extension Service expressed concern in its Long Range Work Program, that many cane fields were becoming pastureland for cattle. This shift is reflected in the statistics for the years 1950-64 and after that period all agricultural activity, including the raising of beef and dairy cattle, showed declines in production. By 1975-76, only three dairy farms were still operating in the municipality according to the Agriculture Department's Agricultural Statistics Annual.

The agricultural activity in Rio Grande can be divided into three distinct periods:
1. Prior to 1898: Coffee
2. 1898-1964: Sugarcane, coconuts, milk
3. 1964-Present: Poultry and eggs.

Aviculture, an activity characterized by small investment requirements in both capital and manpower, has been the only agricultural activity that has remained constant in the municipality. The Agriculture Department has assigned a total of $45,800 for the development of aviculture in Rio Grande.

Government

The impact of the Industrial Development Program established in Puerto Rico in the 1940s can be seen in the creation of agencies for infrastructure development, such as the Water Resources Authority, the Aqueducts and Sewers Authority, and the Government Development Bank. These agencies, together with other government dependencies, invested a total of $53,826,965 in the municipality of Rio Grande during the period 1942-77, or 1 per cent of the total spent island-wide on permanent public works. Table 3 presents a cost breakdown of this expenditure.

The permanent improvement programs, which account for the largest share of educational projects.

Table 2: Agricultural Participation and Distribution in the Rio Grande Municipality

1807 | 1910-1920 | 1980-1940 | 1950 | 1959 | 1964 | 1968-1974

No. of Farms: 462 | 920-500 | B2L | 405564 | HGS

Amount of Land (in Cuerdas): 28,551 | 96,549 | 28,025 | 18,675 | 28,100 | 28,900 | 22,167 | 18,498 | 8,874 | 8,718

Total Planted: 1,261 | 24,937 | 21,702 | 8,291 | 20,100 | 7,756 | 6,734 | 4,094 | 1,885 | 1,455

Sugar Cane: 245 | 2,922,971 | 124.020 | 4.998 | 3.573 | 2.563

Coffee: 424813 | 8358S | HB

Coconut: nd | ond | ond | od | 0,128,272 | 1,201 | UL | 85D | TL

Vegetables: 921082 | nd | 3 406 | KB

Pasture: 16,088 | nd | 2,000 | nd | 12,736 | 11,862 | 12,981 | 10,546 | 3,964 | 5,188

Mountains & Weeds: 11,202 | 11,612 | 6,828 | 10,884 | 3,000 | 4,282 | 8,052 | 8,796 | 2,725 | 1,770

No. of Cows: 7258 | 4185 | 6,793 | 2490 | 4.917 | 4414 | 6,898 | 7,614 | 3,569 | 752

No. of Chickens: nd | 4,882 | 4434 | 4,674 | 6,220 | 6,146 | 8,983 | 12,986 | 17,000 | 25,086

Sources: First Year 1897, Cayetano, State of Puerto Rico's Economic and Industrial Situation, U.S. Census of Agriculture, Puerto Rico, 1910, 1990, 1980, 1989, 1964, 1909, 1974.

Table 3: Total Cost of Permanent Improvement Programs Municipality of Rio Grande (1942-1974)

1. Rural and urban sewers and aqueducts: $9,145,049
2. Rural communities and housing: $717,899
3. Fomento projects: $3,061,651
4. Boery projects: $1,780,325
5. Educational projects: $15,770,868
6. Public works projects: $10,050,461
7. Land Authority projects: $8,408,957
8. Public buildings projects: $1,818,987
9. Recreational projects: $222,489
10. Urban communities and housing: $8,623,574

Total Cost: $55,826,065

Rio Grande's percentage of total: 9 percent

At least partially as a result of these investments, the municipality's adjusted internal income has increased steadily: from $4.2 million in 1950, to $8 million in 1960, to $16.9 million in 1970.

In 1978, the sum reached $25.9 million. The manufacturing sector's share increased from $3.9 million in 1960 to $8.8 million in 1970. The municipal government’s share was $0.6 million in 1960, $0.9 million in 1960, and $2.4 million in 1970.

As part of the public policy to develop the economic infrastructure of the northeastern part of the Island, the Governor of Puerto Rico stated in his 1978 Message to the Legislature that about $24 million would be invested in the area during fiscal 1978-79 for the construction and expansion of urban aqueduct systems to increase potable water supplies. This investment includes the completion of the Rio Blanco filtration plant in Naguabo and the construction of a filtration plant in El Yunque with a capacity of 10 million gallons a day. This plant will utilize water from the Espiritu Santo and Rio Grande rivers. The first stage consists of a retention wall and pumping system to take water from the Espiritu Santo River, while the second will consist of a series of reservoirs. The Aqueducts and Sewers Authority has studied various alternatives for establishing reservoirs in the Espiritu Santo and Mameyes rivers.

Manufacturing is the sector that has had the greatest economic impact on the municipality of Rio Grande since 1950, according to the adjusted internal income figures. Although manufacturing has been able to absorb part of the labor force left idle by the decline of agriculture, a Planning Board study of the geographical movement of Rio Grande’s workers made in 1963 indicates that about 21 percent of the persons employed in the municipality reside elsewhere. The majority of these non-residents, or about 87 percent, are residents of Loiza. The Planning Board cites the principal reason for this situation as the fact that recent improvements to Highway 8 have significantly reduced the economic distance between Rio Grande and surrounding municipalities. The Planning Board estimates that by 1980, the demand for trained workers in the manufacturing sector in Rio Grande will increase.

The number of jobs increased by 6,500. This surge in demand could also lead to an increase in the importation of workers from other municipalities. In 1960, there were nine factories operating in Rio Grande. This number increased to 14 in 1960, 32 in 1970, and then slightly declined to 29 in 1977. Currently, out of the 29 factories operating in the municipality, 22 were promoted by the Economic Development Administration. Nineteen of these are located on Highway 9, from Km 21.0 to 32.9; only one, Systematic Industries, is located in the urban center.

The majority of Rio Grande’s factories, 11 in total, manufacture clothing and related goods. Another five produce stone, clay, or glass products; five make machinery and electrical equipment; two focus on metal products and another two on chemical products. There are individual plants producing wood, paper and related products, and three that produce non-electric machinery.

According to a memo submitted by the Executive Director of the Industrial Development Co. to the La Fortaleza Interagency Coordinator, Antonio Santiago Vézquez, on June 13, 1978, the company is negotiating with Stanric Electrical Equipment for the establishment of an additional plant in Rio Grande. The Executive Director also reported that additional factory facilities are currently under construction as part of the agency's Industrial Urbanization Program. The project is spread over 86 acres and is included in a federal appropriation of $8,080,200.

In addition, the Economic Development Administration is negotiating for the establishment of two new manufacturing enterprises in Rio Grande. One of them, a U.S. based company, would provide employment for 80 persons in the manufacture of metal loops and would have an initial capital investment of $200,000. The second, involving a $118,200 investment of local capital, would manufacture steel structures and create 100 jobs. Currently, the agency has no long-term promotion projects planned for the municipality.

The expansion of the manufacturing sector in Rio Grande has led to urban growth in the area.

Municipality, as can be seen in the following section.

Construction: Construction activity has been concentrated in the development of the municipality's urban periphery. In less than 10 years, projects such as Villas de Rio Grande, Jardines de Rio Grande, Rio Grande Hills, Alturas de Rio Grande, and others have gone up. The Planning Board estimated the value of construction in Rio Grande at $1.02 million in 1955, increasing to $5.78 million in 1960 and $89.22 million in 1970. In other words, construction value quadrupled between 1955-1960, and increased five times during the period 1960-1970. As of December 1977, thirteen new development projects for the municipality had been submitted to the Planning Board. Five of these projects are residential, another five are residential-tourism complexes, one is commercial and industrial expansion. Table 4 provides a breakdown of these projects, the largest of which is the 663-acre Costa Serena development and the smallest is a sports center to be built by the Parks and Public Recreation Administration on a 5,690 square-meter lot.

Table 4: Relation of Approved Projects for the Rio Grande Municipality up to December 31, 1977.

Proposer	Number	Project Date	Classification	Localization	Cuerdas
Rio Grande Dev. Corp.	68.065	11/16/76	Urb/Res. B, Pueblo	Jardines de Rio Grande	92.74
Urbanizadora	70-044	9/28/75	Urb/B, Jiménes y Zarzal	Colinas de las BT Urb	51.66
Urbanizadora Rio Vista Inc.	70.109	8/15/17	Urb/B.Guzmén Abajo	Alturas de Rio Grande	227
Hyatt-Rio Mar	T0419	2/22/77	Tourist-Residential/B, Mameyes	Proj	3200
cruv	72.056CVD	5/18/77	Urb/B. Guzmán Abajo	Alturas de Rio Grande	81
Costa Serena Dev.	72.190	9/28/77	Urb/Residential-Hotel/Boca Herems	Urb	668.0
Neftalí Adorno	73.022	7/14/16	Urb/B. Guzmán Arriba	Reparto Montesereno	29.0
Eas Coles Estates	73.0954	10/18/76	Tourist-Residential/B, Zarzal	Urb	55
Autoridad de Tierras	75-1610PG	8/25/76	Ind. B. Ciénaga Baja	Enlarge Factory	-
aro Dev. Corp.	15:5.0052-SPD	-	Tourist-Residential	-	-

"Urb, 11/29/76 Res. B. Zarzal 19.74 Caribbean Home Const. Corp. 76:22-A-471°CPD
‘Tourist-Residential Urb. 12/8/16" B. Mameyes, 38.15 Centro Plaza 65 Inc. 16-22-A675*CPD
Commercial building 5/24/76 Com. B.Ciénaga Baja 16,023 m* APRP 16-22-A148 CGA Sports Center 1) 1/77 Reo. Urb. Villa 5,530 m*

Housing: According to the Planning Board’s Housing Information System, Rio Grande had a housing inventory of 8,614 units in 1960, of which 93 per cent were occupied. By 1970, the inventory consisted of 5,997 units of which 84 per cent were occupied and by 1977, there were 9,194 units with 92 per cent of them occupied. A total of 9,197 units were built from 1970 to 1977, for an increase of 68 per cent. The Planning Board estimates that there will be a demand for an additional 949 units by 1980, and 4,575 units by 1985. Of the 8,474 units which made up Rio Grande’s housing stock in 1977, 48.5 per cent were valued at $10,000 or more; 86 per cent of these units were owner-occupied and the remaining 14 per cent rented. Only 21 per cent of Rio Grande's rural housing is classified as substandard, and 17 per cent of its rural housing stock. It ranks seventh island-wide in terms of the condition of its rural housing stock, and tenth regarding urban housing.

Commerce: A commercial planning study conducted by the Commerce Department in Rio Grande concluded that local consumers were more attracted to the shopping areas of Rio Piedras and Fajardo than to the municipality's commercial district. On the other hand, Rio Grande's commercial center attracts consumers from the neighboring towns of Loiza, Luquillo and Canovanas. On the basis of projected development, the Commerce Department estimates, however, that the commercial sector will be a major source of employment, goods and services for Rio Grande residents in the future. If the projected growth rate in employment is achieved, the department estimates that the municipality's income will be about $58.2 million by 1985. It also estimates an increase in the demand for

Retail goods of $9.1 million by 1980 were to be absorbed by the shopping centers of Villas de Rio Grande and Alturas de Rio Grande.

Tourism: Potential tourist attractions of both historic and scenic nature can be found in Rio Grande. Among these are the Indian hieroglyphics in the Espiritu Santo riverbed in the Jiménez Arriba sector, the El Verde recreational area, and a number of Spanish colonial houses. The Elisa Colberg Girl Scout Camp is also located in the municipality.

A recently built hotel, Rio Mar, is now operating and the Hyatt International Corporation plans construction of a $160 million residential-tourism complex in the area, which is expected to give an additional boost to the economy. Other such projects are planned, including the Costa Serena development, Las Coles Estates, and projects of the El Faro Development Company and Caribbean Homes Construction Corporation.

The area also offers typical foods and entertainment, particularly during the Feast of the Virgin of Carmel in July and during the Christmas season. The municipality has a Double A baseball team, a cockfighting pit, and a basketball team. In addition, there is a modestly priced boating excursion offered daily down the Espiritu Santo River.

Social Characteristics: The population of Rio Grande is relatively young. In 1970, 76 per cent of the population was under 40 years of age, younger than the island-wide pattern by 2 per cent. In terms of annual average family income, however, the municipality is below the island-wide average. Annual average family income in Rio Grande is $2,798, or $270 less than the island-wide figure of $8,068. Only 47 per cent of Rio Grande’s families have an income above the average figure, while that percentage is 49 per cent island-wide.

The social variable with the greatest impact on the municipality’s integral growth is population growth. Table 5 shows population growth changes in Rio Grande and in Puerto Rico as a whole. It can be seen that the growth rate in the municipality projected for...

1980 and 1985 is nearly three times greater than the island-wide figure.

Table 5: Total Population Year Puerto Rico from Rio Grande

1940: 1,869,285
1950: 2,210,103

1960: 2,349,544
1970: 2,712,033
1975: 3,120,900
1980: 3,531,100
1985: 3,916,100
1990: 4,263,000
1995: 4,528,700
2000: 4,673,400

Source: Junta de Planificación de Puerto Rico

Figure 1 shows this relationship as a histogram.

Official Planning Board population estimates indicate that Rio Grande will reach its greatest rate of population increase by 1980, and that increase is expected to exceed the island-wide figure by 25 per cent. The increase is expected to continue through the year 2000, although at a slower rate. The growth rate will still be 8 per cent greater than that of the island as a whole, however. Also, by the year 2000, population density is expected to reach 1,887 inhabitants per square mile, 29 fewer than the island-wide figure. If these projections prove accurate, Rio Grande will have tripled its population density while the population density of the island as a whole will have increased only 1.5 times.

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Rivers form a riverine type estuary that extends inland for six kilometers. The upper and middle limits of this estuary are composed of agricultural land used for the cultivation of sugar cane and for cattle grazing. The lower reaches are bordered by riverine type mangroves, with the dominant species being Rhizophora mangle, also known as the red mangrove. In some parts of the lower estuary, these mangroves extend onto land where species such as Languncularia racemosa (white mangrove) and Avicennia germinans (black mangrove) are found. In these areas, the mangroves extend inland for a considerable distance. The total area of mangrove in the estuary is estimated at 333.84 acres.

Residents of Rio Grande and nearby towns such as Lofea and Luquillo utilize the estuary and its mangroves for both economic and recreational purposes. Commercial fishing and crabbing carried out in the estuary provide local fishermen with a significant portion of their income. Moreover, the area is used for sport fishing, pleasure boating, and tourism. The municipality of Rio Grande discharges much of its liquid wastes into these rivers after they have been processed by a secondary treatment plant.

The main purpose of this paper is to explore some of the economic aspects of the fauna found in the estuary and its mangroves. A secondary goal is to examine the estuary’s impact on Rio Grande's economy and establish the relationship of the estuary to its surrounding communities, as well as its importance to these communities. To understand the economic significance river estuaries have for the communities that surround them, it is important to have a clear picture of their biological importance to the ecosystem and to the commercially valuable animal life used by these communities.

As recently as 25 years ago, river estuaries and mangroves were considered flood-prone areas, useless wasteland without economic value that served only as a breeding ground for mosquitoes. This mistaken view was held by a large segment of the population.

Influenced both industrial and residential development, it has been responsible for the disappearance of a major portion of our mangrove resources and the pollution of our river estuaries. Approximately two-thirds of the island's mangrove forests have already disappeared and at the present time, it is estimated that only around 15,800 acres remain. Fortunately, this attitude toward estuaries and mangroves has changed as a result of the quantitative scientific studies that have been conducted regarding their biological importance.

River estuaries are now recognized as having significant economic and productive value, and as being of vital importance for the crustacean, mollusk, and fish reserves that represent an important economic resource for the island. The high level of biological productivity of these areas has been recognized by marine biologists and oceanographers throughout the world. A full 90 percent of our fish and commercially valuable crabs inhabit these estuaries during one or more stages of their life cycles. This is also true for such crustaceans as shrimp, freshwater fish, and certain mollusks, such as the oyster (Crassostrea rhizophorae). The larvae of these fish, crustaceans, and mollusks are born in the estuaries or migrate to them because they provide a habitat that is rich in food sources and offers protection from natural enemies unable to tolerate a brackish environment. These larvae remain in the estuaries throughout their juvenile stages and if they are estuary dwellers, remain during their adult stages as well. Thus, the estuaries can be considered natural breeding grounds for the young of commercially valuable species. The livelihood of Puerto Rico's coastal fishermen, and particularly crabbers, depends on the ability of the estuaries to produce and protect these commercially valuable species. The crustaceans, mollusks, and fish found in the Espiritu Santo River estuary are characteristic of those found in all Puerto Rican estuaries. Of the abundant stocks, of...

"Commercially valuable species include the blue land crab (Cordisoma guanhumi), the squatting land crab (Ueides cordatus), shrimp (five species of the Macobrachium genus), and several species of fish such as the bass or labrax (Centropomus spp.), POrEY (Lutjanus spp), jareas (Mugil cureme), barbudos (Polydactylus virginicus), and mojarra or sea-fish (Diapterus plumier). Any factors that adversely affect these species, resulting in a reduction in their numbers, will impact the income of commercial fishermen and crabbers. Businesses such as restaurants and fry-stands that depend on these fishermen for their fresh crabmeat supplies would also be affected. Determining the direct economic impact of such a situation on the municipality of Rio Grande would require a quantitative study of this aspect of the economy.

Materials and Methods

The data used in this paper are drawn from a one-year study of the estuary's crustacean and mollusc fauna. The data concerning fish are limited and were obtained from a preliminary survey. In the mentioned study, six stations were selected from the mouth of the estuary to its upper limits. These stations covered mangroves, agricultural land, and cattle grazing land. In each station, sectors were marked off on both sides of the river, extending to the beginning of the pasture or grassy area, and then subdivided into zones according to the predominant vegetation in each.

The established zones were as follows: Rhizophora zone (dominated by red mangrove); Languncularia zone (Languncularia racemosa or white mangrove); Avicenia zone (Avicenta germinans); Acrostichum zone (Coccos nucifera); and Grassy zone (Panicum spp., Spartina spp.). Areas where two species were equally dominant or one was only slightly more dominant were designated as Transition zones. Finally, two zones were established as Aerial Root zones, where the roots of the Rhizophora mangle extend."

Toward the water, and the Aquatic zone, comprised of the river itself. The longitude of the sectors marked off varies according to the zones contained within them. Specimens were collected in each sector and the size of the stock was determined using the quadrant method for each different species. Thus, stocks could be determined quantitatively for nearly all of the species, with the exception of the Goniopsis cruentata, which is difficult to capture and had to be estimated in a semi-quantitative manner.

In this specific case, the individual specimens contained in a given area (square meter) were counted with the aid of binoculars. Physical and chemical parameters also were determined, including pH, temperature, salinity, dissolved oxygen content, and the existing concentrations of such elements as Ca, Si, Na, Mg, and K. These tests were conducted both in the substrata and in the water. An analysis was made of particulate size in the substrata, as well. During the course of this study, a series of experiments were conducted which provided valuable data regarding ecological aspects of each of the species, with special reference to their reproductive habits and life cycles. The final results of this study will be published shortly.

RESULTS AND ANALYSIS

The data obtained regarding species with economic value for the population of Rio Grande are examined in the following section. Because of limitations of space, the discussion will be confined to certain aspects of general interest. The species with economic value found in the estuary may be divided into four principal categories, or groups, as follows:

Shrimp. Ten different species of shrimp were collected, in either juvenile or adult stages. Seven of these were typical of fresh water, one was a marine species, and the rest estuarine. Of the ten species collected, eight have commercial value (See Table 1). The marine species was identified as Penaeus schmitti, or white shrimp, and was reported recently for the first time on the island (Canals).

1977). This shrimp enters the estuary during its postlarval stage and remains for six to nine months, after which the pre-adults return once again to the sea (Ewald, 1967). P. schmitti is not commonly found in the estuary during its adult stage, but may be seen in great numbers in the river mouth when the moon is full. Some fishermen take advantage of these bright nights to capture this shrimp in nets. They are used chiefly as bait, but occasionally are sold at five dollars per pound. Freshwater shrimp, such as the gusbaras (Atya lanipes and A. innocous), sgnos (Octacrobrachium heterochirus), camaren de afos (M. carcinus), the coyunteros (O. olfers, M. crenulatum), and the sapiche (Xiphocaris elongata) are commonly found in their juvenile stages because they have an estuarine life cycle. The upper reaches of the river are densely populated with adults of these species and some of them, such as Atya lanipes and Xiphocaris elongata, are found in the river from birth. These shrimp are caught all along the Septimo Santo River, especially during Lent (low tide), and their sale price ranges from four to five dollars per pound. The leopard shrimp (Macrobrachium acanthurus) and Potimirim spp. are the exclusive estuarine species; only the first has commercial value and is caught by fishermen either for their own consumption or for sale. In addition to their economic importance, the value of the shrimp for the estuary's ecological balance and food chain is enormous. A study conducted by Luis Coro (personal communication) shows that the larval shrimp are the major food of a great number of the fish varieties found in the estuary during their juvenile stages. Since the freshwater larval shrimp have an estuarine lifecycle and must emigrate to the estuary to develop into adults, any factor which prevents this migration will affect the upriver stock.

Crabs. Fourteen different species were captured, all of which are characteristic of mangroves or estuaries. Three of these are aquatic species, ten are

"Semi-terrestrial, one species can be considered a true land crab (See Figure 1). Of the 14 species found in the estuary, only two, the land crab (Cardisoma guanhumi) and the zambuco crab (Ucides cordatus), are of great commercial value. They are also highly prized as food by area residents. Three other species could have commercial potential, the covolfas or Calinectes spp., and another, the phantom crab, found on the sand beaches at the river mouth, is used as bait in fishing for porgy and red grouper.

The land crab, or palanct (Cardisoma guanhumi), is the species most highly prized by crabbers in the area. It has great commercial value, with the sale price ranging from twelve to fifteen dollars per dozen. However, the populations of this species have greatly diminished in Puerto Rico in recent years. Factors that could have produced this situation include the disappearance of their habitat and over-capture.

This crab inhabits areas above the high-tide line and is found in all zones included in this area. The population is most dense in the Avicenia germinans, or black mangrove areas, and in the grassy zones. This crab has been known to grow to a length of 84 mm, but examples of this size are extremely rare. The average size found in the Espiritu Santo River and its surrounding areas is from 50-60 mm in length.

In its juvenile stage, Cardisoma guanhumi inhabits the river-bank zones, especially in the grassy one, where the water table is not very deep. This is due to the crab's need to moisten itself periodically to avoid evaporation and desiccation. In this zone, population density is 10 to 12 per square meter for juveniles and 1-2 per square meter for adults. In the Laguncularia, Acrostichum, Avicennia and Palm zones, the adults are more common. Depending on the area in which these zones are found, density varies from 3-4 to 1-2 for adults and juveniles, respectively.

The land crab is especially common during the rainy season, particularly during the month of May, when they mate. It is during this time that..."

This month, the first "runs" of the crab take place, when they leave their caves in order to mate. Additional runs occur from June to September when the females travel in groups to the shores of the sea or the estuary to spawn. During these runs, the crabbers' catches increase considerably.

The zambuco crab (Ucides cordatus) is very similar to the land crab but smaller. Its average shell length ranges from 3.40 mm. Its habitat is entirely different from that of the land crab, which can be described as mangrove areas that are periodically submerged by the tides. This crab is found chiefly in the Rhizophora zone but can also be found in the Languncularia and Acrostichum zones when these are submerged in water.

Figure 1: Relative Species Density of Decapods Crustaceans at the Rio Espiritu Santo Estuary.

In the estuary, the zambuco crab is found only in mangrove areas, and it is the species found in the greatest numbers in the mangroves. It is slow and easy to capture. In the Rhizophora zone, the population density is 10-12 per square meter, while in the Acrostichum and Languncularia zones, the density is six and four per square meter, respectively. However, they are found in these last two zones only when they are swamped by water.

This species remains submerged during the day if the tide is high and emerges during the ebb or low tide. It also will emerge following heavy rains during hot weather. Because of the scarcity of the land crab, estuary crabbers have been concentrating on this species, since its meat is equally valued. It is the species caught in the largest number in the estuary and thus of greatest economic importance. The price varies from five to eight dollars per dozen, but is sold mostly in the form of meat at three dollars per pound.

Some 25 crabbers interviewed work full-time at catching the blue crab and the zambuco crab. Each man's catch consists of five to six dozen zambuco crabs and two to four dozen blue crabs daily.

This represents a minimum total catch per man of 95 dozen Zambuco crabs and 14 dozen blue crabs a week. These crabbers as a group have a weekly income of $10,000.00. In one year, the sale of crabs can represent an income of as much as $120,000.00 for 20 crabbers. Individually, their net income averages about $8,000.00. It should be noted that these figures were obtained during the height of the crabbing season and are not representative of a full year. In addition, it should be taken into consideration that the crabs and their meat are sold to the many commercial establishments in the area that specialize in seafood. The crabbers are these businesses' only source of fresh crab meat.

Mollusks will not be discussed in this paper since only one species with commercial value (Cressostreg rhizophorae) is found in the estuary, and the populations are very limited. Area fishermen say the edible mussel (Lucina pectinata) was once common in the estuary, but these populations are very small at the present time. The reasons for this reduction are unknown, but one factor could be current changes as a result of dredging carried out in the area some years ago.

Fish represent a very small number of different species caught. However, this is due to the fact that the data is from a preliminary study. A much more extensive study has been conducted by Iris Corujo, the results of which will be published shortly. In the preliminary study for the purposes of this paper, only 12 species were caught. The most common were the bass, ot Labrez (Centropomus spp., two species), the area (Mugil curema), porgy (Lutjanus spp.) and the mojarra, or sea fish (Diapterus plumieri).

Interviews with 20 fishermen revealed that 12 of them live solely on their income from fishing. Fishermen's income vary greatly, but the minimum range is $60.00 to $80.00 a week. In addition, the estuary is used extensively for sport or recreational fishing.

Conclusions:

1. The Espiritu Santo River estuary has great economic potential.

The text appears to be an academic article or report. Here is the corrected version:

The Rio Grande's importance is significant for many residents. It is also utilized for tourism and recreational purposes. The crab fauna holds the highest economic value. The estuary is crucial for the freshwater shrimp during their larval stage. Any negative changes to the estuary's ecology will affect its productivity, impacting the income of residents who earn their livelihood from fishing and catching crustaceans.

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ECOLOGICAL DESIGN OF RESERVOIRS FOR PREVENTION OF BILHARZIA BY WILLIAM R. JOBIN, Sc.D

There is dramatic evidence that the development of water resources on the south coast of Puerto Rico led to a severe epidemic of the parasitic disease, bilharzia. This disease is spread by freshwater snails which populate the reservoirs and canals of the South Coast Irrigation System, causing severe illness in the nearby population. Therefore, new reservoirs planned for Puerto Rico, especially those in bilharzia zones, should be carefully designed and operated to minimize the spread of bilharzia.

A wealth of epidemiological information available on schistosomiasis in Puerto Rico has made it possible to trace historical trends in the distribution of the disease. Using various diagnostic methods, numerous island-wide surveys have been conducted on the prevalence of the infection, including a final series of three identical skin-test surveys concluding in 1976. The various surveys were analyzed chronologically, and the geographical distribution of the parasite was discussed in light of several major programs related to the island's development. From a few scattered foci present in the early twentieth century, the

The extent and intensity of the disease increased on the south coast after the construction of sugar navigation systems in 1914. After 1953, this major endemic area was brought under control while a new endemic area was developing in the eastern portion of the island, due to the creation of rural communities known as "parcelas." This increased transmission caused by the parcelas had been counteracted in other parts of the island after the Second World War by the widespread construction of water supply systems and by filling of wetlands and channelization of streams on the growing suburban fringes of the major cities. Finally, an expanded snail control program of the 1970s covered most of the newer foci created by the parcelas, except for a small area on the north coast, east of San Juan, (Figure 1). By 1976 only about 100,000 persons carried the parasite, mostly children with symptomatic infections. They lived primarily in the northeastern municipalities of Rio Grande and Luquillo, with isolated groups in the Naguabo and Yauco areas, as well as scattered remnants throughout the classical endemic areas. Complete control of the disease should be accomplished in a few years if the newer drugs become available for wide scale use in Puerto Rico, (Figure 2).

Figure 2: Prevalence of Schistosomiasis in Puerto Rico from Skin Test Surveys, 1963-1976

THE HUMAN WASTE PROBLEM IN RURAL ZONES OF A HIGH RAINFALL WATERSHED BY ARTHUR McB. BLOCK

Sanitary facilities in rural Puerto Rico conventionally refer to a cesspool (020 muro) and absorption system (CSAS) or a septic tank-oil absorption system (ersas). The purpose of this paper is to describe features of rural zones or bands which can contribute to planning problems due to these conventional methods. Most of the remarks which follow pertain to technical descriptions of current sanitary treatment technology, methods of assessing a zoned impact in a watershed, and a suggestion or two for alleviation.

Regarding some rural problems, Figure 1 displays a classic "pozo muro" design, executed in cinder block and very capable of handling many rural wastes, provided that periodic maintenance is undertaken. The influent comes from above, and with stone baffling around the effluent sections, the time before pumping can be 15-25 years. The ST-SAS operates similarly, but the upper drainage does not directly pass through wall openings. Instead, a level field is used (Figure 2) and the distribution of effluent goes through 1/4"-8/8" diameter holes in 4/6 inch PVC pipe. In general, the ST-SAS provides a more even and uniform distribution. It has certain other advantages for sandy soils or mound construction. If a high water table is a feature of the landscape or if periodic soil saturation from heavy rain is a prominent climatic feature, local practice uses tactics to extend the designs of each type of system. Broad-leaved plants such as those of the Musa family (plantains and bananas) can be planted around the pozo muro or at the edge of an ST-SAS leaching field - Figures 3 and 4. Vegetables and pineapple also do well, and the plants can evaporate a good deal of moisture, prolonging the lifetime of desirable soil characteristics. The following considerations should be taken into account when planning the location of family unit plants and/or shared facilities of 5-10 units in small rural areas. Soil characteristics are important with respect to 8 factors. Permeability is low in superficial expanding clays common to the high rainfall watershed. This is not ideal. Usually, a 60 minute/inch percolation of surface water is considered the lower limit. Nevertheless, some modern practices permit rates as high as 120 min/inch. Sometimes, upper soil horizons of tight clay give way to high permeability undersurface and vice versa. That possibility should be checked. An unsaturated soil column of 3 ft is considered the practical minimum; the column may be 10 ft for very coarse soil. These considerations are summarized in Figure 6. Topographic characteristics are also important.

The text primarily concerns the slope or average slope of the drainage field (Figure 6). Generally, the limiting slope for an effective STSAS is 25 percent.

0-10" TYPICAL Figure 1: Detail of “Pozo Muro” (optional stone baffling as shown)

PLANE LAND AREA term of 1Wg-2 GRASS. FOR8 GROUND COVER OR: MUSA, PINEAPPLE, Squash, non-leafy vegetables. Avoid close proximity: Avocado, Mango. Advantage of very even distribution. Figure 2: Top View “Pozo Septico” showing distribution drainage field.

Figure 3:

Soils: PERMEABILITY 120 min/in minimum ST-SAS 60 min/in minimum. Pozo muro DEPTH TO CREVICED BEDROCK 2'-3' fine-grained soil 10'- coarser soil (expanding clay, tuffaceous, etc.) DEPTH TO IMPERMEABLE LAYER 3'- adequate. FIGURE = 4

Topographic: LIMITING SLOPE ST-SAS 25% (may have to level). LIMITING SLOPE POZO MURO 40-45% (Provided 12-15" depth provided). DESIGN LIMITATIONS POZO MURO Upslope side left permeable. Downslope side impermeable. FIGURE =

Consequently, some terrain leveling may be necessary if such a system is employed in Puerto Rico, particularly in higher areas of the Rio Espiritu Santo River (RESR) basin. Actually, a Pozo Muro is effective at up to 45 percent slope provided that it is sufficiently deep (12-18 feet) so either system requires some earth moving. Additionally, several design modifications can be employed in some extreme cases.

Geology of the area can be very important, particularly in areas characterized by stratigraphy including massive andesitic or granitic formations such as found in the RESR basin. In general, shallow bedrock closer than six feet from the surface is limiting. Unstable, heavily weathered soils (quite common in the RESR basin) contribute to drainage clogging, or washout of underfield sections. Soil breakdown, which occurs naturally at a very slow rate, can be greatly accelerated by exposure to wastes from the drainage field. Accumulation of soil organisms' wastes can also clog the field.

The text has several typos and missing spaces. Here is the revised version:

Causing early failure, this is less prevalent in constructions featuring faded rock baffling. These design considerations are summarized in Figure 7. Finally, perhaps the most important engineering unknown which must be determined is an accurate picture of the hydrology of the area for which sewage disposal tanks are being designed. This is summarized in Figure 8. Seasonal high ground water can be very high in land masses draining an area receiving over 200 inches of water per year (such as El Yunque at the source of the principal drainage system of the RESR basin). The accepted limit for the drainage field of an ST-SAS is three feet below the bottom of the drainage trenches. Higher than three feet can cause failure from which field recovery is very slow, or even irreversible. Lateral land use can greatly influence the system. Heavy cropping or maintenance of cleared areas along the sides of the drainage fields contributes to failure in heavy rains. Mountainous modifications of the pozo muro can be made, but more earth-moving and brickwork is required. To accomplish this, an outer-walled tank is constructed, and two floors may also help.

Flooding causes pollution of streams through the failure of drainage fields. As a consequence, excessive fertilization of water bodies and adjoining land areas takes place. This latter effect has been exploited for centuries by farmers in the Yalu, Mekong, and Po River valleys, among others, and, until the construction of the Aswan dam, in the Nile river valley. Let us consider landscape and land use planning options which can be used in order to cope with pollution caused by the failure of human waste treatment plants in rural communities of the RESR basin (Figure 9). Pollution of streams from leaching field failure causes excessive fertilization of estuaries. Is this desirable? Can it be tolerated for brief periods during the year? According to data accumulated by the Terrestrial Ecology Division, it is being tolerated at this time.

Geology: SHALLOW

Bedrock closer than 6ft from surface indicating unstable soils. Sandy soils have a high water table. Fine, highly hydrated sediments are common in swamps and tidal estuaries. Soil breakdown can happen due to capillary clogging and shifting ion exchange in clays (common here). Blockage may occur due to the accumulation of biomass (microorganisms), precipitation of metal sulfides, and excretion of slimy polysaccharide gums by soil bacteria.

Figure 1: 82

Hydrology: Seasonal high ground water limit is 3° below the bottom of the drainage trench. Failure of the field is at 24*. Lateral land use such as cropping soil can impede recovery. Mountainous modification can be done with a walled bottle Pozo Muro (lower wall on downslope side). Flooding can cause pollution of streams (heavy) and excessive fertilization of estuaries (useful 2, harmful 2). Strategies can contain 7, live with it, or try to channel it.

Figure 1

Planning elements to consider are: locate the "best" areas for BAS treatment using soil, topography, geology, and hydrology characteristics. Perform necessary modifications of land. Try to connect 610 living units to a single sewage line and use gravity feed to channel to a single drainage line. Use gravity feed to channel to a single drainage field. No more than one field can be constructed every two acres. Use design considerations such as maintaining access roads for provision of tank pumping (by the municipality) every five years. Locate the most convenient right-of-way and channel all sewage to a central processing plant, eliminating rural or semi-rural drainage fields altogether. This option is very expensive. Finally, carry out onsite inspections of all rural fields, determine which are failing and require redesign and restructuring of the associated facility. New designs should include modifications of traditional modes of construction to reflect the realities of topography, soils, etc. Where this cannot be carried out individually, owing to these same realities, conduits for transportation of waste should be constructed to channel sewage to a separate treatment plant in developing new sections of a.

Municipality, one of the planners' first considerations, is model development. This model should not only include traditional elements such as estimates of the number of patrons, number of dwelling units etc., but should begin to include geographical information on adjacent land areas suitable for sewage drainage. This is especially important if central sewage collection and treatment is not economically attractive.

Illustration and exercise: Construct a Mylar overlay showing areas characterized by soils having light to moderate limitations as septic tank absorption fields, for the RESR basin. After the overlay, demonstrate which rural barrios are amenable to community or shared facilities, and which will need closed sewer transference of sewage to a central processing plant. Hint: Use the 1969 National Cooperative Soil Survey maps.

ACKNOWLEDGEMENTS

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I wish to acknowledge Dr. William R. Bhajan for his helpful discussions of rainfall and coliform bacteria data related to conclusions that the estuary of the Espiritu Santo River is heavily fertilized. Finally, I would like to thank my friends and neighbors in Barrio Carraizo Alto for providing historical viewpoints of rural sanitation practices in Puerto Rico.

PRECIPITATION DISTRIBUTION AND RAINGAGE NETWORKS IN THE LUQUILLO MOUNTAINS BY BRENT N. HOLBEN, J. A. COLON,

MIGUEL CANALS, FELIX SANTOS, and R. G. CLEMENTS - Page 87

INTRODUCTION

The spatial distribution of precipitation in Puerto Rico demonstrates nearly an order of magnitude of variation from the driest to the wettest areas. For example, the southwest coastal section receives less than 90 cm (36 in.) annually, while 60 miles to the northeast, the peaks of the Luquillo mountains have been reporting amounts exceeding 685 cm (250 in.) in a year (Calvesbert, 1970).

Two stations in the Luquillo mountains, El Yunque peak and USWB Station at El Verde (1000 M and 1100 M elevation respectively) are separated by a horizontal distance of 5 Km. A twelve-month precipitation record from February 1976 to February 1977 showed 432 cm (170 in.) had fallen at El Yunque while only 102 cm (40 in.) was measured at El Verde.

Certainly, this and other dramatic variations make spatial estimates of precipitation difficult in tropical montane rain forests such as those in the Luquillo mountains. Other investigators have studied the frequency of rain events in these mountains. Wadsworth (1948) reported a total of

1,635 rain showers on 269 days of a year at La Mina while Baynton (1968) recorded measurable precipitation on 360 days during a year at Pico del Oeste.

Weaver, Byer, and Bruck (1978) recorded precipitation on 849 days, 70 per cent of these days received less than 1.25 cm (0.5 in.) of precipitation. All of the above data were taken near the high peaks of the Luquillo mountains. Knowing the spatial extent of these data is necessary to apply them in management decisions.

Clements and Colén (1975) have demonstrated the importance of the abundant, light, frequent showers in maintaining a nutrient supply to the forest canopy at El Verde in the Luquillo mountains. Their data indicate that the first 0.75 mm (0.08 in.) of precipitation would yield the greatest concentration of nutrients available for foliar absorption. Again, knowing the spatial distribution of light shower frequency becomes vital to knowing the magnitude of foliar absorption.

Absorption in a forest ecosystem. Bogart et al. (1964) regard precipitation in terms of a hydrologic budget. They reported runoff to be much higher in the mountain watershed than in lower drainage areas. They stress that their conclusions are based on few data points and state that further research is necessary. River and stream discharge is being monitored and annually published in the Water Resources for Puerto Rico, Part I, Surface Water Records by the USGS. The most significant missing component is the spatial distribution of precipitation, particularly in the poorly accessible high-precipitation areas of the mountains. 58

All previously mentioned investigations were basically point investigations. No thorough attempt has been made to measure precipitation on a spatial basis. With a knowledge of the spatial distribution of precipitation, management of our natural systems become more predictable. Similarly, intelligent planning for future natural resource management demands a thorough understanding of the system without which the wildlands can easily be overexploited, permanently altered, and hence rendered unproductive. It is for these reasons that a study was undertaken to determine the precipitation input into the entire forested watershed of the Rio Espíritu Santo. The purpose is to determine spatial precipitation patterns over that watershed and develop a data base to more easily estimate the number and spatial distribution of rain gauges necessary to monitor precipitation patterns and spatial amounts in the mountains of Puerto Rico.

MATERIALS AND EXPERIMENTAL DESIGN

The basic instrument used was a storage rain gauge constructed from an eight-inch diameter plastic funnel connected to a five-gallon collapsible water bottle by a flexible hose. The funnel was held above the canopy by an aluminum arm attached to a tree top. Each funnel was placed sufficiently above or away from the canopy so that precipitation to the funnel was unobstructed. The number of stations and

Monitoring intervals were determined primarily by logistic and manpower constraints. The watershed is remote, mountainous, and accessible by temporary trails. These characteristics combine to make monitoring difficult and at times dangerous. Therefore, a network of twenty rain gauges monitored biweekly was decided upon. The twenty storage rain gauges (stations) were placed in staggered rows at 0.75 Km intervals across the watershed. When lines connect adjacent stations, a web of 23 identical equilateral triangles is formed. (See Figure 1.) Each triangle has an area of 0.28 Km^2 and the total network covers 6.44 Km^2. The watershed in question, of 5.87 Km^2, is, except for small areas, included within the network. This design has the advantage of easily converting point data to spatial data. The three points which make up each triangle may be averaged to yield a precipitation depth for the area of the triangle. It can be shown that, for the grid network in Figure 1, the equilateral has the smallest ratio of area to corner points of any polygon that can be drawn. This is desirable when assigning a precipitation to an area. The most data points for the smallest area renders a more accurate value for that area.

Figure 1: The position of numbered rain gauges is superimposed on a contour map of the forested Eaftitu Santo River Watershed. Dashed lines connecting adjacent rain gauges illustrate the structure of the triangle grid.

All stations were checked by the authors from February 1976 to February 1977. After each monitoring, intercepted volumes measured at each station were converted to an equivalent precipitation in centimeters and inches and cataloged for analysis.

ANALYSIS

The concept of grid density is basic to this analysis. Two types are used, the number of stations per Km^2 and the number of triangles per Km^2. The station sensitivity yields point data which is sensitive to precipitation variations. This type of grid should be used if isohyets are desired. The triangle grid is used to assign an average

The depth of precipitation in an area is derived by averaging, which reduces its sensitivity to extremes. The analysis must proceed on two fronts, one dealing with distributions based on point data and the other with spatial depths based on triangle averages. In all comparisons, existing stations are used, which limits the diversity and coverage of grid densities to be tested. On all tested grid densities, the equilateral triangle configuration was maintained. The surface coverage was also maintained as close as possible to that of the original grid coverage, i.e., 6.44 Km^2. The actual grid density was calculated from a new grid network. Configurations were calculated from the area enclosed by the new network. The original twenty stations and 25 triangle grids were reduced to 6 stations and 4 triangles, 4 stations and 2 triangles, and finally 3 stations and 1 triangle. See Tables 1 and 2 for a listing of corresponding areas and densities.

The point data were analyzed as follows: Annual precipitation was calculated for each station and that number was properly placed on a map of the watershed. Isohyets were drawn according to the following criteria: At least two stations must lie on either side of the line. The smallest isohyet interval was determined for the 20 station grid. The number of intervals between isohyets were counted and assigned to that grid density. The same procedure was carried out for the other grids. A greater number of intervals represents a more efficient grid in determining the precipitation distribution.

For the triangle analysis, the average precipitation depths are calculated for the area covered by the new triangle grid and the same area using the original 0.28 Km^2 triangles. These are labeled "Calc. Precip." and "Actual Precip.", respectively, in Table 2. The depths are compared for each grid density and between grid densities. The mean precipitation depth for the original grid is used as a standard. Deviations from that mean represent lesser efficiency.

RESULTS

Precipitation Distribution: Figure 2 illustrates the precipitation distribution based on one year of data. The watershed is located on the leeward side of the Luquillo mountain range, primarily with elevations decreasing towards the west. This is manifested through decreasing precipitation from East to West. Perturbations in this pattern particularly occur in the Southwest section where the sharp topography significantly alters the valley's homogeneity. Precipitation levels range from a high of 429 cm (169 in.) at El Yunque to a low of 267 cm (106 in.) on a peak on the southern border. Both sites are at approximately the same elevation, thus the position is an important factor regardless of elevation. Station 15, on the immediate leeward side of the low NS ridge, demonstrates the localized increase in precipitation that has been widely reported to occur under similar circumstances. Figure 2: Isohyets and station precipitation in cm. and (in.) are shown for one year of record in the forested Espiritu Santo Watershed.

GRID DENSITY

Table 1 presents the results from the station grid analysis. This table indicates that a high density of stations is necessary to accurately monitor precipitation variations in this area. Table 1 shows the number of stations, grid density, interval width and number of intervals.

None of the other grids could favorably approach the number of intervals resulting from the 20 station grid. Unfortunately, grids between 6 and 20 stations could not be tested with the existing grid arrangement. The theoretical minimum number of stations which could achieve 7 intervals is 9 stations under the criteria given here. In nearly all situations, a much higher number would be needed. The authors suggest a grid of approximately 15 to 20 stations in this size area (2.8 Sta./Km to 8.1 Sta/Km) to achieve a 25.4 cm (10 in.) interval.

TRIANGLE GRID ANALYSIS

Table 2 presents the results of the triangle grid analysis. This table is distinct in its...

In contrast to the previous table, it seems that total precipitation can be reasonably well estimated from a few stations dispersed throughout the study area. The following table presents the data:

Tanger	Kim	Prec.	Pre Beve
23	36	350.0	3500
6.47	4	09	332.2
4114.80	8	2	04
338.6	345.2	5.07	3
1	02	327.9	3411

These data suggest that if a 4 percent error can be allowed, a single triangle consisting of three stations (low density grid) may be adequate for determining the spatial precipitation depth over a large area. Two important considerations should be borne in mind when using these data to develop a low density grid.

First, this analysis was made with the philosophy that the area in question changes to conform to the grid. However, in most real applications, the grid must be designed to conform to the area. Second, calculated precipitation depths were applied to areas within triangle boundaries; they may well apply outside those boundaries.

Conclusion:

These data strongly suggest that precipitation distributions in the Luquillo mountains require a high-density monitoring network to sufficiently delineate varying precipitation regimes. In contrast, a very low-density monitoring grid in triangle format is sufficient to approximate spatial precipitation depths. We suggest that a density of 2.9 Sta/Km* to 8.1 Sta/Km* would be adequate to achieve a 28.4 cm (10 in.) isohyet interval in these mountains. A much smaller density of 0.2 triangles/Km* or 0.7 Sta./Km* is suggested as necessary to monitor the spatial amount of precipitation to within + 5 percent of the real value.

These suggested densities and triangular distributions are recommended for areas where there is little or no prior knowledge of the precipitation climate of the region. An investigator with a priori knowledge could easily design a more efficient monitoring network to meet his specific needs. Finally, we suggest that our grid densities may be valid in similar regions of high orographic rainfall.

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HYDROLOGY OF THE ESPIRITU SANTO RIVER BASIN

BY: RICHARD G. CLEMENTS

INTRODUCTION

Our current knowledge of the hydrology of the basin is very limited. One of four main concerns in this initial research effort was to determine or establish the general relationship between rainfall and streamflow. A survey of the literature in Puerto Rico revealed that very little, if any, effort has been concerned with this important relationship. Also, attempts to determine this relationship to date have not been successful. Estimates based upon average annual data were presented by Bogart (1964) for 10 upland areas using data compiled by the Water Resources Authority (See Table 1, ‘Average annual rainfall, runoff, and water loss in mountain areas of Puerto Rico. Data from PRWRA records after Bogart, 1964).

250. 200. 2 2 = 150- 3 = 3 5 100. ae . s . 8 ~ 3 ; 50 a 0. ° 50 100 150 200 Average annual runoff, inches
Figure 1, Average annual rainfall and runoff of 10

Data from PRWRA records areas (after Bogart, 1964).

While the data suggests the general relationship, much more detailed measurements would be required to provide reliable, predictive equations that could be used for management purposes. Such generalizations should be used for informational purposes only. Unfortunately, they often become a part of the planning process and are used in the estimation of the water budget, which could lead to serious consequences. Throughout the report, caution was emphasized in the interpretation and extrapolation of the relationships set forth. Frequently it was not possible to validate the relationship between rainfall and runoff due to insufficient range in drainage basin. In some cases, only one rain gauge was in operation where stream discharge measurements were being made.

The following is cited from the discussion by Bogart (1964) on drainage and rainfall: "Even though the total rain at the Rio Hicaco gauging station (in the Luquillo Mountains) is much greater than that on most of the Island, the daily variation of discharge is typical of what might be expected on most small streams in the mountain areas of the Island. It is obvious from the graph (graph not reproduced in this report) that one or two observations per day are not likely to provide a reliable average flow for a day on which heavy showers occur... continuous recording, therefore, is essential."

The average daily runoff at the Hicaco gauging station is compared to the daily rainfall a mile south (downstream) of the gauging station and 560 feet lower in altitude, in the following table.

September 1952:
Rainfall, inches - 8.34, 9.94, 0.272...
Runoff, inches - 1.02, 5.76, 7.39, 7.51, 8.08...

The inconsistency between rainfall and runoff is to be expected when the rainfall is measured at only one gauge, but the comparison illustrates the inherent weakness in rainfall-runoff comparisons in Puerto Rico. Not only does much of the rainfall occur in short local showers, but the terrain is so mountainous in the interior of the island that interpolations between rain gauges will not necessarily be accurate.

This text represents the average rainfall on drainage basins. Rainfall data can only provide general estimates of streamflow, and only for long-term averages. On the other hand, a gauging station equipped with an automatic continuous water-level recorder, when properly operated, will yield a reliable record of the actual streamflow. It is the stream flow that concerns the designer of water facilities.

The latest water research investigations have followed the same course for the last 75 years. Of the cooperating government agencies, three are directly concerned with the utilization of freshwater. One of the original functions of the Water Resources Authority was to develop the headwaters of rivers and provide electrical energy. As a result, this organization was more concerned with the volume of water flowing from selected rivers rather than the relationships between rainfall and runoff. Therefore, the investigations from the first part of the century have been directed towards the measurement of streamflow for the design, construction, and maintenance of reservoirs.

The Aqueduct and Sewer Authority was established as a public corporation in May 1945, with the purpose of providing the people of Puerto Rico with an adequate water and sanitary sewer service. Consequently, the agency has been interested in how much water will be necessary to supply the required needs of the people. The Puerto Rico Industrial Development Company assists and aids industry in meeting their water demands. While these agencies have been concerned with the question of "how much water", no one has given serious consideration to "how much is being received" via rainfall and what is the relationship between the two.

It appears that the installation and measurement of rainfall with rain gauges developed independently from various water resources programs. As of 1960, over 80 stations across the island were reporting rainfall on a daily basis. Over the years, this network has provided valuable data with regard to the general rainfall distribution of the

Island ‘Table 1: Average Annual Precipitation and Its Distribution Based on the Water Resources Authority Analysis (Bogart, 1964)

Area (Square Miles)	Percent of Island Area
20	130
28	40
258	16
60	195
81	60
396	18
0	923
210	80
705	22.4
90	453
13.2	100
79	52
00+	11
35	Total 3420

*Includes the Islands of Vieques, Culebra, and Mona.

While this type of tabulation provides an overview, it is of little value in more detailed hydrological studies of a basin, such as the Rio Bstritu Santo. The effect of slope has not been properly evaluated in any of the hydrological studies conducted on the Island. That it is important in the consideration of rainfall input to an area can be deduced from a theoretical treatment of rainfall adjusted for slope as shown in Table 2.

Table 2: The Relationship Between Slope and Effective Rainfall

Base is 254 cm (100 in.) per year.

Percent Slope	Effective Rainfall	% of Theoretical
25	258.7 cm	100
10.0	258.0 cm	100
26.0	245.9 cm	97
40.0	238.7 cm	93
53.0	224.5 cm	88
80.0	198.4 cm	78
100.0	179.6 cm	n

In the 1971 annual report, the Environmental Quality Board presented a breakdown of land area by percent slopes (See Table 3).

Table 3: Land Area by Percent of Slope, Puerto Rico

Percent of Slope	Area (cuerdas)
0-5	404,778
6-15	178,451
16-35	349,738
36-45	83,414
46-59	177,852
60 or more	626,418
Total	24141 100.0

*The study excluded the offshore islands as well as some 85,000 cuerdas in “urban or non-productive use”.

Approximately one third of the land is classified as having slopes in excess of 60 percent. If a mean of 80 percent is assumed (See Table 2), this would mean that the effective rainfall received is only 78.1 percent of that received incident to a horizontal surface. In absolute terms, 254 cm annually as measured by a standard rain gauge would only be worth 198.4 cm of effective rainfall when adjusted for slope. This is a reduction of approximately 56 cm (22.0 inches) on an annual basis. In many instances, the slopes in the mountainous areas may exceed 100 percent.

At around 48 degrees, slopes would approach a 100 per cent incline, and at about 60 degrees, the reduction in rainfall would be 50.7 per cent. Within the study area, there are inadequate rainfall records for hydrological studies. The earliest recorded rainfall on the northwest slopes of the Luquillo Mountains was likely reported by Wadsworth in 1970. This gauge was operated from 1912 to 1960 at or near El Verde, which is at the entrance to the Luquillo National Forest at an elevation of 195 m. During this period, the average annual rainfall was reported to be 280 mm (129 in.). Rain gauges were operated from 1942 to 1945 on the upper Espiritu Santo River and at Ciénaga Alta. Rainfall records have been maintained at the El Verde Field Experiment Station since 1963, with a gap in the record from 1968 through 1969. No attempt was made to determine the relationships between rainfall and streamflow in this area. Today, the gauge at the El Verde Field Experiment Station is the only one in operation on the northwest slopes of the Luquillo Mountains.

Within the study area, data are available for two stations on the Espiritu Santo River. Station number 638 is located in the lower reaches of the river about one mile upstream from Highway 8, and Station number 633 was situated inside the forest and near the El Verde Experimental Field Station. However, station 633 was discontinued in 1974. Station 638 was established by USGS in 1960, and is located at an elevation of 40 feet MSL, draining an area of 8.62 sq. mi. Only annual flow measurements were made from February 1959 to April 1963. Since 1966, complete records are available for stream discharge. The six-year average from 1967 through 1972 was 58.1 efs-day, equivalent to 91.58 inches per year or 42,090 acre-feet per year. During the period of record, the maximum measured discharge was 10,200 cfs on October 21, 1972, while the minimum observed was 6.0 cfs on April 8, 1970. A summary of the yearly

The records are given in Table 4. 3.

Table 4: Surface Water Records for Station Number 688 on the Espiritu Santo River. Values are in ef.

Year_Annual Mean Max. Min, CFSM Inches Adres Feet

1968 20,667 56.5 643 6.1 6.55 8896 40,990

1969 25,959 71.2 1250 79 826 112.15 51,540

1970 32,821 89.9 1340 5.0 1040 141.66 65,100

1971 16,724 45.8 631 65 531 7218 33,170

1972 17,587 48.0 593 75 5.57 75.69 34,700

1973* 17,654 48.4 9526.5 BBL. 76.21 35,017

* Preliminary Data

Station number 688 had the highest CFSM value reported for the Island during the calendar year 1972. Generally, the stations with the highest CFSM values are found in the eastern part of the

Island and at the higher elevations. In 1975, a climatological study was initiated in the upper reaches of the Espiritu Santo River (forested area) to determine the spatial and temporal distribution of rainfall over this 1400 acre tract of forest. Refer to Section on Climatology and correlate rainfall with streamflow records from Station 633.

Unfortunately, we soon learned that Station 683 was discontinued in 1974 and no further records would be available. Thus, the opportunity to establish the relationship between rainfall and streamflow was dealt an unexpected defeat. We then turned to an indirect approach to investigate the relationship and the results are encouraging for the first phase.

The streamflow records for USGS Station 642 (Rio Grande, south of the town), Station 638 (0.5 m. south of Highway e on the Espiritu Santo) and Station 633 (inside the forest) were summarized according to the years of record (See Table 6).

The results are given in terms of average daily cfs values for each year. The data were then subjected to a correlation-regression analysis to examine the relationships among the stations.

Table 7 summarizes the general relationship between Station 638 and 633 for the years of common record, 1969-1973. Using Station 688 (lower station on the river) as the independent variable, we examined the potential of predicting streamflow at.

Station 633 (Upper Bain, which was eliminated in 1974), the results obtained show an extremely high correlation, R?=0.944, and the equation derived is: Est, Flow Sia, 638 = 6.687 + 0.89935 where: 6.687 is constant and X = streamflow at Sta. 638.

Average Daily CFS:

1967 - 345, 18.0, 4.7

1968 - 58.8, 29.8, 56.5

1969 - 88.5, 316

1970 - 102.3, 40.5, 89.9

1971 - 25.8, 45.8

1972 - 24.0, 48.0

1973 - 25.4, 48.4

1974 - 28.7, 55.9

1975 - 43, 447

1976 - 25.4, 418

*Water Year is October through September. Station 688 versus 683.

Percent "Yer 688 633688 Deviation:

1969 - 347, 376, 1

1970 - 89.9, 2a, 405, 35

1971 - 45.8, 247, 25.3, 24

1972 - 48.0, 256, 240

1973 - 484, 25.7, 25.4, 12

1974 - 55.9, 28.7

1975 - 447, 24.3

1976 - 418, 25.4

Station eliminated

Applying this equation, the estimated values for Station 633 were calculated for the years of record and are shown in Table 7 under column Y. The estimated values deviated from the actual values as shown under the heading Percent Deviation in Table 7. Taking into consideration the various uncertainties involved, the general agreement is excellent. Thus, utilizing the equation developed for the relationship, we are able to estimate streamflow at the point previously monitored as Station 633 by utilizing the continuing records of Station 638. In view of these results, our next step is to examine the relationships on a more detailed basis and then reconstruct or estimate the discharge of Station 633 for the one-year period in which we monitored rainfall over the upper basin. These data will then be utilized to examine the relationship between rainfall received over the upper basin and the resultant discharge. If successful, this will be the first case of documenting the relationship between rainfall and streamflow in Puerto Rico.

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COMPREHENSIVE

TECHNIQUES FOR INVENTORY AND ANALYSIS OF NATURAL RESOURCES

By Dr. Eugene E. Crommett

INTRODUCTION

The environmental design process may be defined as the creative alteration of the existing natural and man-made environment, with the intention of improving the community's quality of life. For the designer, the starting point of his efforts is the physical environment as he perceives it to exist and that requires an imaginative and useful reorganization.

There is, of course, room for lengthy debate concerning the correct ordering of human priorities and aspirations in order to determine what would constitute an improvement in the community's quality of life. There can be little doubt, however, concerning the potential that our "designed" environments have for intruding upon, even for disrupting existing natural and social systems.

We intend and hope for the best, but the general result of our design efforts is probably in every instance a mixed bag of positive and negative impacts on previously existing conditions. While creative imagination can never be replaced as a fundamental component of the design effort, it must be guided by rational processes, and these rational processes need to be stimulated and informed by sensitive observation and reliable scientific information.

The creative act is a primal process which remains largely a mystery, but the validity and relevance of the physical products of the creative act must meet the test of rational thinking. In a word, the environmental designer ought to be held accountable for the impacts upon the existing environment which result from the application of his creativity.

Though it may sound redundant at first thought, we can say that the environmental designer ought also to be an "environmentalist," concerned not only with initiating changes in the existing physical environment, but also with the short and long-range impacts of his efforts upon it.

ENVIRONMENTAL DESIGN AND HOLISTIC THINKING

The holistic view that has so often enlightened...

Researchers in ecologically oriented fields often begin to sense the intricacies and far-reaching implications of their findings, a sensation that is not new to design professionals. Environmental design is fundamentally holistic in its comprehension of the relation of the whole to the parts of an environmental system. Further, the design process is iterative and autogenous in its method.

Just as in natural systems, a small alteration in an environmental design - whether it be a building, a park, a town, or a region - can set off a chain reaction which will require adjustments throughout the whole system. A large alteration or several significant changes in the design may cause such an imbalance in the system that it may be preferable to scrap the initial overall concept and start anew.

The similarity and suggestiveness of the ecosystem as a model for the design process has led some to identify man-made environments as ecosystems. Many environmental designers find themselves conversing comfortably with holistically-oriented scientists from the ecological and social sciences.

Not only is "seeing the system as the whole of all the parts" virtually intuitive to the environmental designer, but so too is "putting the whole thing together from its parts." This certainly implies that the competent designer is a capable coordinator of a large number of facts and details. However, "putting the whole thing together from its parts" is not a simple additive process; rather, it is an iterative one. The designer attempts to follow the lines of influence and feedback stimulated by the internal adjustments of small components of the system to each other and to the whole.

Reaching a reasonably stable balance within the parameters of the time and funds available for solving the problem, and within the limits of their creative talent, the designer allows the system to "gel" and proceeds to finalize drawings for construction. Exactly when and under what conditions the designer brings the system to "gel" implies a practical dimension, as...

His selection of scientific and technical data, which is relevant to the project at hand, often distinguishes the designer from the basic researcher. This might explain the difference in orientation between the two. The designer must eventually, often sooner and rather arbitrarily, establish a cut-off point for analysis and creative fermentation in order to proceed with the construction of his environmental design. The researcher, on the other hand, often seeks more time to pursue his investigations to their logical conclusion or beyond.

Nevertheless, those involved in basic research in ecologically-oriented fields are usually delighted when designers show sincere interest in their data and express a desire to apply them to the design process. While the designer may appear to simplify the researcher's complexities, he does indeed progress to assemble the whole project and give it practical application.

To say that we are encouraging a multidisciplinary effort here is to underestimate our intention. I would be more inclined to state that researchers and designers of the environment need each other.

The competent environmental designer has several advantages at his disposal, closely associated with his talents and education. His comprehensive study and application in the design process, in basic science and engineering, and in the humanities and social sciences, complement and enhance his respect for what his senses tell him. This marriage of creative intuition with logical thought, along with his ability to communicate both verbally and visually, is crucial. He often insists on understanding how something works in addition to being told how it works. As an environmental designer, he often feels a kinship with scientists involved in the study of environmental data and issues.

Above all, he is a likely candidate for synthesizing their findings in a comprehensive, graphic, and analytical manner. His primary interest is to apply their findings to the design process itself.

"Lead to a responsible and enlightened reordering of the physical world.

METHODOLOGY FOR RESOURCE ANALYSIS AS A BASIS FOR DESIGN DECISIONS

1. Comprehend the major components of the natural and human environmental systems in a specific region.
2. Emphasize the dynamic character of these components as opposed to viewing them as fixed or static conditions.

3. Summarize the most reliable and detailed environmental research for graphic modeling without oversimplification.
4. Translate all information to a unified graphic form so that the various components may be viewed and studied as integral parts of a system.
5. Devise an analytical technique that brings numerical and conceptual models nearer to the physical environment as actually experienced in everyday life.
6. Document the presentation so that it will readily lead back to the basic research data, and so that corrections in the presentation can be made in light of an altered or enlarged data base.
7. Aid the designer in the estimation of human deployment of resources as an essential parameter of the design process and of probable impacts of predetermined uses upon the environment:
   a. From the point of view of the intrinsic capability of the natural and human systems for supporting these uses and/or impacts.
   b. From the point of view of the best alternatives among proposed uses in light of estimated impacts.
   c. From the point of view of the formation of public policy for areas of special or unique value as natural or social systems.

Although the list of major components of the system under study will vary according to locale and objectives, it will generally include the following:

1. Topography
2. Slopes by percentages
3. Geology
4. Soils
5. Hydrology
6. Fauna and Flora
7. Biosystems
8. Scenic values
9. Points of social interest
10. Climatology
11. Microclimatology
12. Environmental pollution
13. Present land use
14. Present land ownership
15. Socio-economic data
16. Master plans adopted or studied

It can be seen..."

Many of the components listed above are comprehensive in nature, having several sub-components. Among several of the major components, there are reciprocal dependencies that resist oversimplification. For example, the sequence: soils, slopes, hydrology, geology, flora. All the components are in fact interrelated, and those researchers who are accustomed to carrying on specialized study in one or two areas should quickly become aware of this. Indeed, this is one of the objectives of the methodology.

Basic data is received from specialists and their assistance is given in its interpretation and organization. A translation is then made, often only after considerable thought and effort, from the numerical and conceptual models of the specialists to the graphic analogues of the presentation. Where graphic models are already utilized by specialists, the translation is usually easier. In those areas where data does not yet exist — such as Scenic Analysis, Points of Social Interest, or Microclimatology — the design professionals carry out the needed investigations.

A base map is prepared by tracing the prominent features of a C&GS map(s) of the study area, in ink on drawing mylar. Topography is not usually included on the base map drawn at this scale. The required number of mylar copies of the base map is reproduced on a standard Ozalid plan copier using mylar which is glossy on the upper face and matte on the reverse side. Information is applied to the reverse (matte) side of the mylar in the form of colored areas using Eagle “Primacolor” pencils, following a consistent system of coding. Some data is applied to the glossy side of the base map in the form of logos attached with glue. Each major component of the area under study is graphically presented on one or more of these mylar maps. In addition to the maps, the “dynamic section” is also employed. This is a graphic, multicolored section taken at indicated points through the map, and shows dynamic processes.

The text has several typos and formatting issues. Here's the corrected version:

Relations not readily discerned in the maps themselves are addressed. Pictorial drawings, charts, and lists with appropriate symbols are also employed to enhance and amplify the information presented on the maps. In some cases, such as the Soil Capability study of Scenic Analysis, drawings of highly informative matrices are presented in order to further document the internal analysis of a major component. The maps and drawings are mounted on white drawing panels of the same size (0” X 40", for example) with a logo-title block to give further visual unity to the whole presentation. The materials employed in the presentation are not costly and are readily available: drawing Mylar, colored pencils, India ink, glue, and white drawing presentation board. Copies of the presentation can be circulated among interested researchers and designers in the form of colored slides which can be projected to the actual size of the original panels. Primary and secondary research materials, which have been utilized in the preparation of the inventory and presentation of data, are carefully indexed for quick reference at any time, and for proper documentation of sources and their future use. Analysis of the information contained in the inventory and its presentation actually begins as it is reviewed for summary and conversion to graphic analogue form. It is especially important that those who prepare the Mylar inventory maps and other visual devices be the same persons, or that they work closely with those who collate and review the data to be presented in the inventory. This constant exposure to all of the data will contribute greatly to their comprehensive grasp of the many components involved, and will facilitate a more effective analysis of the data that takes place when the inventory presentation is completed. To organize the data depicted in the Mylar inventory maps in a consistent way, and to facilitate the application of a comprehensive analytical technique that may be applied to diverse kinds of data, a system similar to the method is suggested.

The work of Ian McHarg in Design With Nature has been adopted. Among the colors and tones employed to depict varying conditions and processes on each map, the darker shades are generally used to represent factors which, when impacted by development projects proposed by man, would present maximum difficulties and costs, or that would threaten those areas more appropriately left in a state of preservation because of intrinsic natural or social values. A very steep slope, for example, would be shown as a darker tone, as would flood-prone land or an area containing rare flora or fauna.

Our method departs from that of Professor McHarg in one aspect: While he employs maps as overlays with the intention of identifying the variation of accumulated density, as many transparencies are added to the pile, in order to determine intrinsic capability of potential impact in the face of development, we find that this method becomes unwieldy and illegible when more than a few overlays are combined.

We proceed then from the maps through numerical matrices which represent the varying intensities of tones, to summarize the numerical tones of all the maps, and then return to a graphic representation of the resultant matrix. In applying this numerical technique, we are well aware of the fact that the numbers themselves represent nothing more nor less than the judgements we have initially made before converting the tone densities to numerical equivalents.

The analysis of each major component in the resource inventory is accomplished by placing over each mylar map another mylar sheet ruled off in squares, the sides of which represent a known scaled distance on the map (For example: 0.5 Kilometers). The fineness of this grid, which we call the "matrix grid" can be adjusted to fit the scale and objectives of the study. Each square is identified with conventional matrix notation, i.e., A = (a), which provides a method of location on the maps and facilitates computer programming for the summing of corresponding squares in large datasets.

The number of individual matrix grids. As the blank matrix grid is placed over each map and aligned with it, reference is made to the information that appears within each square, and to the information contained in the dynamic sections, diagrams, charts, and even in the original sources of the data, in order to assign a scalar value to the individual square for the map being analyzed. Once all the squares in a major component mylar map have been evaluated in this manner, the numerical matrix which results can be read into the computer for storage under the title of the component. The computer program follows the simple routine of adding the corresponding squares of all the map matrix grids to produce a final matrix which models numerically the sum of intensities of all of the major components. From this final numerical matrix, a map can be prepared which represents with varying densities of tone the degree of resistance or accommodation to development (or other assumed factor) of the sectors of the area under study. Those accustomed to rather sophisticated mathematical models employed in specialized areas of study may feel uncomfortable with the simple value scales which we employ in our method. Without engaging in a lengthy discussion concerning scientific epistemology and the question of the validity of abstract models for empirically observed data, we should point out that: (1) practical decision making and the establishing of public policy usually involves people who quickly bypass complex models and demand to know, “Should we develop? Yes, no or under what circumstances? (2) experience shows that we can handle the nuances of graded scales at the practical level from two to perhaps a maximum of fifteen or sixteen shades of value; (3) the decisions concerning the allocation or deployment of resources count heavily upon summary conclusions derived from baseline data, a process we will have already followed in the preparation of the inventory presentation; (4) our method will be useful in its...

Application to a particular area is to the degree that we have analyzed neighboring areas as well. (5) We can and should return to the basic data for clarification and amplification of tentative decisions based upon the matrix analysis. We have chosen a scale of 1 to 5 as a numerical representation of a series of five tones or intensities of color. To give meaning at the design and planning level, we tentatively adopted the Florida scheme, identifying “5” as representing “preservation” where no development or negative alteration in the natural system should take place; “3” as representing “conservation” where certain controlled development or human activity may be allowed to take place when natural systems can absorb them without serious negative impact; and “1” as representing “development” where carefully conceived development projects can be accommodated with minimal impact. The values “2” and “4” are intermediate terms for borderline cases. The adjustment of the scale as a whole, that is, a definition of just how much and what kind of development the designation “1” envisions, or just how extreme our preservation efforts ought to be for areas designated as “5", will depend upon the overall “holistic” view of the area under study, the dominance of one or several highly determinant factors, and public policy considerations viewed from the regional or island-wide perspective.

PERSPECTIVE OF THE METHODOLOGY

If the method outlined above were to accomplish nothing more than to make specialists, designers and planners aware of the intricacies and mutual dependence of the various components of natural and social systems, it would more than justify the effort and small expense involved. For the most part, the data base for making the inventory and analysis already exists for many areas. That it should be interpreted and utilized for a practical purpose needs no argument. Furthermore, as data is translated into the graphic analogue form, gaps and inconsistencies often appear. The method can then be viewed as a

Corrective and motivational device for specialists. In the case of the designer, the inventory and analysis creates an enhanced environmental consciousness in him. It provides him with a comprehensive tool for altering natural and human systems according to their own natures and built-in economies. He has the opportunity to give substance to the self-designation "design ecologist." As a middle term between practical comprehensive decision-making and a database often compartmentalized into diverse areas of specialization, the method is analogical but accurate, qualitative without ceasing to be quantitative, simple without being simplistic, and above all, it is economical and available.

GRAPHIC ILLUSTRATIONS

Four black and white photographs of original 30" X 40" full-color panels with Mylar maps, a typical "dynamic section", and a graphic legend are included in this report.

Plate No. 1 is a reduced illustration of the map of slopes by percentages (Mapa de Pendientes) for a study of the Fajardo-Icacos area of Puerto Rico. Shown are the 30" X 40" presentation panel with the Mylar colored map frame mounted. Below the map (left to right) are the logo title block, the legend showing tones representing slopes by percentages with notes on suitability for different uses, and a graphic legend relating the slopes as specified by percentages to the actual visual appearance of the slopes.

Plate No. 2 is an enlarged photo of this graphic legend.

Plate No. 3 shows the presentation panel for the major component "hydrology" (Hydrologia) from the Tortuguero area study. Flood plains, bodies of water, recharge zones, run-off, etc., are indicated. Below the framed Mylar map is a "dynamic section" (shown in an enlarged view in Plate No. 4) depicting the complex aquifer and underground water system in the area, the balance of pressure between the freshwater overlay and the saltwater penetration from the nearby sea. Included in this section is a representation of the topography and general vegetation types.

Well, as the geological structure as it bears upon hydrology.

Mapa de Pendientes Ton Ava

98 Fuente de Informacion Uso de los Cuadrangulos de Fajardo - Icacos Areas de Pendientes Logadas con la Topografia Bon Suv

Plate No. 8 Vidiohigih Sen D Owa Eiol

Plate No. 4.

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THE CORPS OF ENGINEERS EXPERIENCE IN WATER RESOURCES PLANNING IN PUERTO RICO by: Lt Col. Joseph A. Beben, Deputy District Engineer of Puerto Rico and Virgin Islands, Jacksonville Engineer District 93

INTRODUCTION

Unlike most of the ongoing studies in the United States, the water resources management studies in Puerto Rico are subject to special Congressional authorization. Puerto Rico enjoys a unique position since 1970 when Congress gave the Corps of Engineers broad authority to address the water resources problems and needs of Puerto Rico, in cooperation with the Commonwealth Government. Dr. Antonio Santiago Vazquez was then the Secretary of Public Works, and he and others such as Prof. Leonard Dworsky of Cornell University were instrumental in securing this program for the Commonwealth. In this legislation, Section 204 of

In the 1970 Flood Control Act, Congress provided for a cooperative effort between the Corps of Engineers and the Commonwealth Government. The legislation was extensive and pertained to both inland drainage basins and coastal areas. It called for the preparation of plans for the development, utilization, and conservation of water and related land resources. The Corps of Engineers responded by establishing a special study group in the San Juan Area Office, which has maintained a staff of seven to ten professional planners and engineers since 1972. This study group coordinates its efforts with all appropriate Commonwealth agencies, with the Department of Natural Resources as the primary contact. Implementing the mandate given by Congress in 1970 has proven to be both intriguing and beneficial for the Corps and the Commonwealth. Conceptually, the Corps fully recognizes that the Commonwealth of Puerto Rico has undertaken significant planning over the years, and we certainly would not presume to diminish the importance of past and current Commonwealth planning efforts. On the contrary, we have always been willing and interested in coordinating our planning efforts with those of the various Commonwealth agencies involved in water resource management. Initially, we struggled due to inexperience and a lack of appreciation for local problems and institutions. It has taken us nearly six years to produce the Ponce study report if we trace back to the very origins of the group effort. Thus, one cannot truly say that we have posed a threat to the livelihood of other water resource planners up until now. Currently, Dr. Emilio Colén and his staff in the San Juan Area Office have the following studies in various stages of completion:

1. The Island Wide Water Supply Study examines the water supply needs of all the other

municipalities outside the Ponce region for the next 50 years. It is 50 percent complete.

2. A flood control study for the Ro Piedras/Rio Puerto Nuevo.

The project was initiated this year and is approximately 80 percent complete.

8. This month, we will initiate a flood control study for the entire basin of the Rio Grande de Lofea. The study is expected to take three years to complete.

4. Dr. Colén's staff has just completed a reconnaissance report for improving flow conditions in the Matting Pea Canal. We are recommending both dredging and flow augmentation, and funding for construction appears imminent.

5. The Puerto Rico-Virgin Islands Pipeline Study is also just getting started. This multi-purpose study is examining aspects of water supply, flood control, irrigation, hydroelectric power, and recreation in Eastern Puerto Rico.

6. Reconnaissance level flood control studies under section 205 (Small Flood Control Projects) have also recently been completed in four areas in South Puerto Rico. The reports from Arroyo, Peñuelas, Yauco, and Sabana Grande are currently under review at higher headquarters.

7. A Detailed Project Report has been initiated to address the flood problems in Coamo, as a result of an approved section 205 Recon Study. In addition, the District staff in Jacksonville is conducting studies for beach nourishment at El Tague and Punta Salinas, navigation improvement in San Juan and Ponce Harbors, aquatic plant control for the entire island, and several floodplain studies for the Federal Flood Insurance Administration.

The following section will examine in detail the Ponce Study, which was completed at a cost of more than $2 million.

PONCE REGIONAL WATER RESOURCES MANAGEMENT STUDY

The first major product of the Cooperative Study Program is the Ponce Regional Water Resources Management Study. The primary objective of the study was to develop and evaluate alternative water resources management plans to meet the future needs and goals of the fourteen municipality region along Puerto Rico's south coast. The study included aspects of water supply, wastewater management (on a limited basis), flood control, recreation, environmental enhancement, and hydroelectric power.

The potential study area consisted of the following municipalities: Gusnica, Yauco, Guaynilla, Penuelas, Ponce, Juana Diaz, Villalba, Santa Isabel, Coamo, Salinas, Guayama, Arroyo, Patillas, and Maunabo. These 14 municipalities encompass an area of about 734 square miles, with a 1970 census population of about 440,356 persons. After receiving Commonwealth guidance, the first step in the development of the study was the completion of a plan of study. The first edition of the plan of study was published in March 1974, and copies were furnished to interested Federal, Commonwealth, and Municipal bodies concerned with planning and related land resources in the south coast area. Their review and subsequent comments were incorporated in a revised publication in July 1974. Intended to be a viable and dynamic tool for use by planners, the plan of study outlined and discussed study objectives, work tasks, federal and non-federal participant coordination, and public involvement procedures, estimated costs, and manpower.

The potential for wastewater reuse involves the utilization of all or part of the effluent from the three regional sewage treatment plants currently planned for the area in the municipalities of Guayanilla, Ponce, and Guayama. The effluents can be used with no further treatment other than the secondary treatment provided at the plant, can be used exclusively for irrigation, and can be piped to storage lagoons near the fields where they are to be used. These waters will not be introduced into the existing main irrigation canal system nor used for municipal and industrial purposes. We are pleased that EPA regulations issued last year specify reuse and land treatment as the preferred method of wastewater treatment. Evaluation of the study area aquifers has shown, generally, that groundwater development has equaled or exceeded safe yields. In a few limited cases, some groundwater sources have been proposed to be replaced by either surface sources, wastewater reuse, or management measures.

The text is revised as follows:

In order to develop an integrated distribution system, low demand water supply plans were developed to provide the study area with 349 mgd by the year 2035. These needs are divided into 230 mgd for agriculture, 58 mgd for municipal use, and 84 mgd for industrial users. The development of water resources within the study area would be sufficient to meet future water demands.

High demand water supply plans were also developed, aiming to provide 525 mgd to the study area by 2035. All four plans proposed require the construction of reservoirs, which may have significant environmental impacts during their construction phase. These plans also involve interbasin transfer from outside the study area, which could be a major issue under economic, social well-being, and environmental evaluations.

Additional available developable groundwaters come from irrigation return flows and are estimated to reach approximately 22.1 mgd. The flood control plans of the Ponce Regional Study have been directed to seven river basins along the south coast of Puerto Rico. These basins are in the vicinity of seven communities: Rio Yauco near Yauco, Rio Guayanilla near Guayanilla, Rio Matilde near Ponce, Rio Coamo near Coamo, Rio Salinas near Salinas, Rio Guamani near Guayama, and Rio Nigua near Arroyo.

Three flood control alternative plans were developed for each stream, addressing different levels of protection. In addition to the structural improvements proposed under each of the flood control plans, nonstructural measures were also considered. The most significant is the implementation and enforcement of Planning Regulation No. 18 for the Control of Building and Land Development in Floodable Zones by the Puerto Rico Planning Board and the implementation of the Federal Flood Insurance Program. Both measures are assumed to have been implemented for all the plans.

A summary of the highlights of the Ponce regional study findings follows:

INSTITUTIONAL ARRANGEMENTS: The present institutional

The framework needs to be streamlined, and the large number of agencies involved with primary functions dealing with water and related land resources needs to be reduced. This will better solve the problems related to the development and management of the water resources in the study area. Furthermore, the current water charges are below the actual costs of development and delivery and are considered as an indirect subsidy to agriculture, industry, and individual consumers. This limits the expansion of the system and promotes inefficient use of the resource.

For land use, the adoption and implementation of the Planning Board's Land Use Plan will allow Commonwealth officials to adopt a water resources management plan compatible with those presented in the Ponce report.

As for water supply management, there is sufficient water within the study area to support a modernized agriculture with some 50,000 acres of land under irrigation, as well as a moderate growth in the industrial sector and the municipal water demand. Greater future development would require the transfer of water from the north coast of the island and a relatively high capital investment. The public should be educated about the water-conserving capabilities available with certain appliances and fixtures. However, conservation measures cannot solely be depended upon to reduce the demand for water. Higher sugar yields can be obtained through the establishment of modern irrigation practices and considering plant consumptive requirements in water applications.

In terms of wastewater management and reuse, treated effluents from the planned Regional Treatment Plants offer an excellent opportunity as a source of water for irrigation. There will be significant volumes of treated wastewater available, concentrated in a few localities, which can serve as a source of water for irrigating crops. The reuse of treated wastewater provides both additional volumes of water and nutrients for the crops. Some of the water supply plans call for the reuse of treated wastewater for irrigating agricultural lands.

By the year 2000, there is a potential of approximately 64 million gallons per day (mgd) of treated wastewater that can be allocated to irrigate approximately 15,000 acres of land. Since the cost of treating the wastewater is considered a sunk cost, treated wastewater provides one of the cheapest sources of water for agriculture. Despite the proven economic advantages and technological viability of wastewater reuse, the Commonwealth Government has not yet established its policy in this area. This is a most urgent policy issue that the Commonwealth Government should consider.

In terms of Flood Plain Management, flood plain regulations (Planning Board Regulation No. 13) and flood insurance should be implemented immediately. A public awareness program for the evacuation of flood-prone areas, as well as warning systems, could help to reduce damages to areas subject to flooding. Encroachment into the flood plains should be avoided except for uses compatible with frequent flooding. Strong emphasis must be placed on the need for structural improvements because much of the flood plains have already been developed and developable lands on the island are a limited and scarce resource.

Requirements and other items concerned with stating the study problems and identifying approaches to their solutions were also developed. As part of our intent to engage the public in the planning process, a public involvement plan was established. One of the principal objectives of this public involvement program was to learn firsthand the concerns of citizens in the region and the relative priorities placed on these concerns.

A major element of the public involvement program was the creation of a study assistance committee. The committee consisted of the study manager, study area mayors, legislators, other public officials, affected special interest groups, private citizens, and any other groups or responsible individuals wishing to voice their opinions for the purpose of influencing the planning process. Special interest groups were represented as well.

The committee included members from environmental, industrial, trade associations, professional consultants, and educational institutions. The primary function of this committee was to communicate the desires, concerns, and opinions of various publics to the study team through meetings, workshops, seminars, and correspondence. It was not an easy task to keep everyone informed. We had over 1,200 individuals, agencies, organizations, and commercial and industrial firms on our mailing list before the study was completed.

The planning process of the study included four identifiable steps:

1. Problem Identification
2. Formulation of Alternative Plans
3. Impact Assessment
4. Evaluation

Several interactions of these steps took place. With each cycle, emphasis was placed on the next step. Through an extensive coordination and public involvement effort, both structural and nonstructural plans were formulated to address one or more of the planning objectives.

After alternative plans were formulated, the economic, social, environmental, and institutional impacts of these plans were developed. Seven water supply plans were developed to meet the needs of two future scenarios for the study area. Three plans for a low demand level, and four for a high water demand level. Plans developed for each scenario range from management measures to capital-intensive measures including, where applicable, wastewater reuse.

Each plan covers a 50-year planning period beginning in 1985 and has an interim plan to cover the time required to review, design, and begin the implementation of the plans. All plans took into consideration the Portugués and Cerrillos Reservoirs, a multipurpose water resources development project currently being developed in Ponce by the Commonwealth of Puerto Rico and the Federal Government.

Management measures considered in the plans include pricing, public awareness, groundwater regulations, plumbing codes, and fixtures.

Outdoor Recreation: The recreational plans...

The PRWRMS under consideration will open new possibilities for the residents of the study area to enjoy outdoor recreational activities. Hydroelectric Power: Conventional large-scale hydroelectric power development sites are no longer available in projects related to the study area. However, opportunities exist for generating small amounts of electric power using interbasin diversion schemes. Opportunities for developing adequate pumped storage systems also exist, but only when inexpensive excess energy is available.

Environmental Enhancement: Development has removed much of the study area's vegetative cover. High levels of erosion can be readily observed, resulting in the premature filling of existing reservoirs. A large-scale reforestation program could be developed for the production of commercial timber and protective cover, which would also provide additional habitats for wildlife.

Conclusions: Let me turn to some general conclusions I have formulated as a result of our study experience to date. I am sure there is little doubt that the Government of Puerto Rico recognizes the need for adequate management of its water resources. The decision to embark on the Ponce Study with active participation from Commonwealth agencies is an example of how interrelated water planning problems were dealt with in a coordinated fashion. So, it can be done. A final product is available and decision-makers not only have its conclusions but also recommendations to implement the plans.

However, these will gather dust on the shelf if we fail to realize that in the final analysis serious constraints are placed on those called upon to implement these plans. I want to briefly touch upon three of these constraints:

1. Financing large-scale endeavors in Puerto Rico is a major problem for anyone who has dealt with the government for any length of time. The difficult economic situation affecting the island in recent years has curtailed many important projects, including water resources construction programs.

The main financing method is through the sale of bonds, which are dependent on U.S. market conditions. In recent years, Puerto Rico has faced significant difficulties selling these bonds. The fee-charging system for the services provided by PRASA and PRWRA is also problematic. Traditionally, PRASA's pricing system has been used solely to collect operating revenues and pay off capital improvements bonds, not to generate revenue for investment in new facilities or to encourage water conservation.

Water rates should accurately reflect the real cost of producing, treating, and delivering water to specific users, including the cost of constructing new plants. However, people are often unwilling to pay more for a basic commodity like water, and political opposition can be expected to obstruct the establishment of adequate pricing structures.

When it comes to water supply, federal funding is generally unavailable. The Farmers Home Administration can assist with small rural water systems, but recent federal legislation has trended towards directing other categories of funds through local governments. This gives them broader authorities and allows the funds to be used in a more flexible manner.

However, if a mayor does not fully understand the water issues in his area, he may allocate funds for other activities. In terms of wastewater treatment facilities, there has been a significant increase in federal funds, resulting in Puerto Rico struggling to find the required 25% matching funds.

In summary, the prospects for project financing look bleak. Not much new construction for water supply can be expected in the near future. On the other hand, the construction of wastewater treatment facilities is probably moving as fast as funds can be efficiently utilized.

The second constraint affecting water resources activities in Puerto Rico is the existence of approximately eight

Commonwealth agencies dealing with the subject. We have PRASA, PRWRA, Planning Board, Natural Resources, RQB, Ports Authority, Transports, Education, and Public Works, Permits & Regulations. Efficient coordination mechanisms are lacking, as well as common criteria for evaluating objectives and alternatives. The picture is further complicated when we add numerous federal agencies that also influence the Commonwealth's planning, financing, and implementation activities. This influence is felt basically in terms of regulations, availability of matched resources to carry on selected activities, and areas of total federal responsibility by law which overlap with local areas of responsibility.

Finally, it is a fact that government policies are articulated and decisions made within a context of competing needs and scarce financial resources. We find competing needs with respect to water supply, flood control, and wastewater treatment on one hand, and basic requirements such as education, health care, and economic stimulus on the other. In order to deal effectively with these competing needs, it's of the utmost importance that there be a clear and well-coordinated water policy for Puerto Rico. The Governor, within the context of his overall development strategy, must take appropriate steps to establish clear and sound priorities which will serve as a guide to other government instrumentalities which through their actions can affect the water resources policy. These bodies include the Legislature, the Bureau of the Budget, PRASA, DNR, regulatory agencies, and other agencies with responsibilities overlapping or affecting the development of water resources.

For this to occur, we are well aware that first someone has to recognize that such need exists and then take a leadership role in terms of doing something about it. Our agency is willing to be of assistance, but this is clearly a decision to be made at the Governor’s level, with input and advice from all those concerned. I have limited myself to... (text ends abruptly)

These three basic problem areas exist, but there are others. If the government can focus on these salient issues and take appropriate steps, we would find ourselves moving ahead in a much swifter manner in dealing with water resources problems. The Corps hopes that the final version of the Ponce Study, to be published soon, will be of help towards this end.

RIVER BASIN: PLANNING: METHODOLOGIES AND INSTRUMENTS AN ANALYTICAL APPROACH

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INTRODUCTION

River basin planning, as it has evolved in the United States and other parts of the world, is not currently practiced in Puerto Rico. This is so for a variety of reasons, the most important being the structure, elements and process of the Island's planning system, and the physio-geographic characteristics of its natural environment. This does not mean, however, that river basin planning could not be carried out here. The key is to determine those elements of river basin planning compatible with Puerto Rico's particular conditions and adapt the river basin planning process to the Island's needs.

The problem, then, is to establish the bases, or the frame of reference, within which such planning activities could be applied locally. Of necessity, this process would focus primarily on the U.S. experience, because of the nature of the relations between Puerto Rico and the United States and because of the pervasive role of the federal government in the management of Puerto Rico's natural resources.

This paper aims at suggesting the ways in which river basin planning could be applied here, and how the findings of the research being conducted by the Center for Energy and Environmental Research can be incorporated into that planning process.

THE CEER AND THE PLANNING PROCESS

A survey of the work being carried out by the CEER in the Espiritu Santo River Basin suggests the need to tune that research effort to the planning structures and

Processes are carried out in Puerto Rico. Perhaps the best way to understand this is by defining what the CEER is not. The CEER is not an operative, normative, or planning agency; it is a center for scientific research. As such, its main responsibility is scientific investigation, and its output is a wealth of data and information that could be useful in the planning process and the formulation of public policy. The data and information collected and interpreted by the CEER could enhance and greatly improve the policy-making process. However, the planning process as such belongs elsewhere, and policy decisions are outside the realm of the CEER. The CEER is neither more nor less than a scientific and advisory entity. Its role is to provide data and intelligence, separate from the day-to-day policymaking process. It is vital, however, that this data and information amassed by the CEER be taken into consideration in Puerto Rico's planning process and in the formulation of public policy.

THE CONCEPT OF RIVER BASIN PLANNING - ORIGIN, OBJECTIVES AND CHARACTERISTICS

The field of regional planning, at least in the United States, grew out of the concept of river basin development. The most outstanding examples of U.S. regional planning involve some of the nation's vast drainage basins. The concept of regional planning has a distinctly developmental origin; it was intended to permit the development of physical resources and it revolved around overall development in very large river basins, covering thousands of square miles, defined as planning regions. This development was multipurpose in nature, and included such aspects as flood control, development of navigational capacity, generation of hydroelectric energy, irrigation, recreation, water purification, erosion control, reforestation, and the exploitation of mineral resources. The classic example of this developmental approach is, of course, the Tennessee Valley

Authority. The TVA is a government entity created in 1933 by an Act of Congress in response to

The need to provide economic recovery during the Great Depression led to the establishment of the Tennessee Valley Authority (TVA). The TVA is unique as it operates independently from any other federal department or agency, enjoying substantial administrative autonomy. It has been the most successful of the U.S. experiments in river basin development planning, although it has also been the most controversial.

River basin planning was initiated in response to the need for social and economic development in underdeveloped areas. The development and exploitation of natural resources were seen as logical and effective means of promoting economic recovery and growth. Subsequently, river basin planning expanded to include environmental concerns, such as water quality management, conservation, and the development of recreational resources.

In summary, the development of river basin planning has been a dynamic process. It originated in the economic crisis of the 1980s as a utilitarian means of generating economic activity and evolved with the environmentalist focus of the 1960s and 1970s. Now, let's examine the characteristics of river basins that have been selected for planning.

River basin planning is generally associated with large land areas. For example, in the United States, river basins extend over several counties and/or states, necessitating the involvement of a large number of public officials at all government levels in the planning process. This aspect will be examined in greater detail below.

In the case of the St. Lawrence River Basin, two nations are involved, the United States and Canada. The Tennessee Valley Authority extends over seven states. A similar situation exists in the river basins of Mexico, although the jurisdictional overlap is of a different nature.

As an example of the extent of individual river basins in the United States, the Mississippi River Basin covers 1,249,700 square miles, while the Columbia River Basin covers 258,000 square miles. The Tennessee Valley Authority has...

Jurisdiction spans over a 29,000 square mile area, and the Willamette River Basin in Oregon covers 11,400 square miles. Another characteristic associated with the river basin as a planning subject is the endowment of natural resources within its confines. The major resource of a river basin, of course, is water. River basins in the United States have a primary function to provide vital freshwater reserves for residential, industrial, and agricultural use. They also provide water for hydroelectric power generation, navigation, and recreation. In addition, river basins are important sources of agricultural land, forest reserves, fish, and wildlife.

The role of the federal government is central to river basin development in the United States. This is first, because of the heavy funding commitment necessary to carry out this kind of development, and secondly because of the adoption of a national objective for the development of river basins endowed with natural resources and the transference of the powers necessary to execute such development. The deliberate effort of the federal government, under the mantle of the New Deal, to develop poverty pockets made available the financial resources needed to begin a development program at the river basin level. However, the availability of funds alone is not sufficient to permit this kind of development; administrative power and will are also necessary.

As stated earlier, the vast river basins that have been selected for development planning in the United States cross city, county, state, and even national lines. Any effort to implement comprehensive development plans for these river basins necessarily involves a complex pattern of overlapping jurisdiction at various government levels, and a workable administrative scheme must be devised to bring all these jurisdictional levels into harmony. In the case of the TVA, the problem was solved in a novel manner by creating an

The text is an independent and administratively autonomous public entity that bypassed the jurisdictional complexities within the river basin's boundaries. The Act of Congress that created the Tennessee Valley Authority (TVA) in 1983 had the effect of creating a kind of regional department of natural resources in the Tennessee Valley. The TVA is a federal agency which assumes the form of a government corporation, and at the same time, it is a regional agency with broad powers for the integrated development of water and resources related to water. It has been aptly called a regional department of natural resources (Martin et al., p. 255). The TVA was intended to provide for the seven-state area it comprises a comprehensive, overall resources management previously carried out in a disjointed manner by a whole range of government agencies, each acting independently of the other. The execution of a development program, concentrated in a river basin drainage area, by a single regional agency, was an innovative approach and the creation of the TVA represented a completely new approach to natural resources management in the U.S.

The most significant aspects of this new approach were twofold: the transference and consolidation within a single regional agency of the disparate functions of the federal government; and as a result, the establishment of a public policy, or national objective, aimed at promoting the comprehensive development of a river basin. Despite its success, the TVA, and especially its hydroelectric power generating function, has been a center of controversy since its inauguration. As a matter of fact, the independent federal entity created to carry out a specific regional development program represented by the TVA has not been duplicated in subsequent regional planning efforts. In terms of river basin development, other administrative schemes have since been implemented with varying degrees of success. These include the basin interagency committee, exemplified by the Missouri River Basin, and the interstate.

The compact agency model, as exemplified by the Delaware River Basin, is unique. Perhaps due to its controversial nature, the Tennessee Valley Authority (TVA) remains the only example of a federal public corporation created to handle river basin management. Despite this, it continues to be the most successful of these experiments.

The planning process and governmental structure in Puerto Rico differ significantly from the river basin planning in the United States. This difference stems from the unique characteristics of the basins themselves and the strategies devised to implement this type of regional development planning.

In Puerto Rico, both the planning process and the delivery of government services are centralized within the central governmental structure, not within a single agency. Unlike the United States, where there is no tradition of national planning, Puerto Rico's planning system is designed to carry out centralized, comprehensive planning.

The type of regional approach to development planning that resulted in the TVA, an independent agency administering the overall development of a selected region, would be challenging to implement within Puerto Rico's existing planning structure.

The inter-agency and interstate arrangements created for the management of other significant U.S. drainage basins would also be extremely hard to implement in Puerto Rico. The island's planning system preempts those possibilities. Its centralized governmental structure eliminates the jurisdictional overlap found in U.S. development planning.

Even the municipalities, the only local political entities with a jurisdictional role in the island’s river basins, have very limited responsibilities. Furthermore, the fundraising capacities of the vast majority of these municipalities are severely limited. Although their powers in terms of development planning are not necessarily restricted by law, they are constrained due to a lack of resources.

"The planning process in Puerto Rico is conceived as a multilevel, multisectoral system, integrated and coordinated by the Planning Board. With its reorganization in 1975, the Planning Board was established as a coordinating and integrating body, its chief responsibility being the provision of an overview of future development, both in policy formulation and evaluation. Thus, sectoral plans are subject to Board review and approval to ensure their compatibility with overall planning goals, objectives, and strategies. The Planning Board relies on five basic planning instruments to carry out its coordinating and integrating function:

1. Comprehensive Development Plan: The purpose of this plan is to establish the policies and strategies necessary for the comprehensive development of the Island, taking into consideration the most pressing social, economic, physical, and environmental problems. The process includes evaluation of existing public policies, and recommendations regarding future allocation of available resources.

2. Land Use Plans: The goal here is the establishment of policies and standards for the management of land and water resources compatible with the policies and strategies established in the Comprehensive Development Plan to guide both public and private investment in land and water resources.

3. The Four Year Investment Program: This program provides a financial analysis mechanism that, together with the Land Use Plans, will permit the gradual implementation of the Comprehensive Development Plan.

4. Planning Regulations: These shape the public policies established by the Board, offer guidance, and establish standards for the channeling of social, environmental, and economic activities.

5. Periodic Reports to the Governor: The Board submits periodic reports to the Governor and the Legislature on the country's most pressing problems, the results and consequences of existing policies, and on the most important physical, social, and economic changes occurring in the country."

Development Process: These instruments provide the Puerto Rican government with the means to carry out long-range, comprehensive planning for the various sectors of the island's development. Theoretically, the centralized governmental structure makes such planning feasible.

There are several important elements outside Puerto Rico's planning process that have an effect on that process. Chief among these is the role of the federal government in Puerto Rico's planning system. The federal government plays no formal part in that process, but in practice, its impact is significant.

For example, the U.S. Army Corps of Engineers has jurisdiction over all navigable waters, making it necessary to involve them in any planning effort at the river basin level, since most of these are connected to coastal areas. In addition, U.S. legislation regarding water quality and pollution control regulations are binding on the Island. This legislation affects land use, development, and investment priorities, with significant impact on drainage basins. The federal government also has a direct impact on the local government's funding capabilities because of the administrative requirements and constraints included in the grant-in-aid that make up a sizable portion of the development funds available to the local government.

The River Basin as a Subject of Planning: The above sections provided a general view of the development of river basin planning and the different planning instruments available in the United States and Puerto Rico for the implementation of development planning. It would now be appropriate to examine how these concepts can be applied to the Espiritu Santo River Basin.

As noted above, the river basin has been set aside, in the United States and other countries, as a planning region, or subject of the planning effort, without regard to the political boundaries it crosses. We have mentioned examples where a single river basin includes several cities and

Counties, several states, and even more than one nation, as in the case of the St. Lawrence River Basin. The planning efforts that have been carried out in these great drainage basins involved a variety of planning instruments, but in all cases, the concept is that of comprehensive planning. This is a global, all-encompassing scheme designed specifically to handle all aspects of development of the subject of planning. In the case of the TVA, as mentioned above, the federal government went so far as to create a public corporation with fiscal independence and bond-issuing capabilities to carry out this comprehensive planning for a single river basin. In general, both theory and experience have shown that a river basin should meet the following tasks in order to be a viable subject of comprehensive planning:

1. Contain an endowment of natural resources that could form the core of a development program.
2. Contain a clientele for the benefits and the costs of such a development program.
3. Be of sufficient size to make development of its natural resources feasible and have access to a large enough market to justify the costs of such development. This market could exist within the geographical confines of the river basin or at a viable economic distance from the river basin.

The following section will explore the degree to which the Espiritu Santo River Basin can be considered a subject of planning, in terms of its compliance with these conditions.

THE ESPIRITU SANTO RIVER BASIN AS A PLANNING SUBJECT

It can be seen at a glance that the Espiritu Santo River Basin does not meet all of the conditions that have been present in river basin planning elsewhere. Its size limitations alone represent a significant factor - the river basin encompasses only 10.6 square miles, while the river basins that have been treated successfully as planning subjects cover vast land areas comprising thousands of square miles.

In addition, Puerto Rico's planning structure militates against the implementation of the kind.

The comprehensive river basin planning practiced elsewhere is not practiced in Puerto Rico. Although planning regions do exist within the island's planning framework, they are mostly operational or administrative in nature. There is no public policy in existence involving the comprehensive development of the Espiritu Santo River Basin, nor is there a comprehensive policy for the development, preservation, or conservation of its natural resources. Instead, the various aspects of the river basin and its natural resources are included in the pertinent island-wide policies or programs established by different government agencies, such as the Department of Natural Resources' coastal zone program and the Aqueducts and Sewers Authority's water resources management programs. Additionally, the federal government is involved in some aspects of resource management in the Espiritu Santo River Basin through its management of El Yunque national forest reserve.

The lack of a comprehensive public policy for resource management specifically designed for the Espiritu Santo River Basin, however, should not be interpreted as implying that no public policy exists that affects the river basin. Several local and federal agencies have established public policies that affect the basin; what does not exist is a public policy that treats the river basin as a single planning subject and covers all aspects of the development, management, preservation, and conservation of its natural resources.

As a result of this approach, situations arise in which a clear conflict can exist. For example, the U.S. Army Corps of Engineers recommend the damming of reservoirs in the river basin at the same time that CEER has produced evidence of a high incidence of bilharzia in the area. The implications of this conflict are obvious: A reservoir project cannot be evaluated without taking into consideration its effects on the ecosystem of the area in which it is to be carried out. An exchange of information and data is vital because planning is a process.

It is not a document. Indeed, an effective planning process can exist without necessarily resulting in a document. In addition to the kind of conflict described above, the Espiritu Santo River Basin is affected by public and private development projects conceived and carried out without regard to its ecosystem. The river basin has undergone rapid urbanization, a process that is still continuing, and there is a high degree of mobility among area residents. Tourism, residential, and industrial and commercial development all pose problems in terms of the management, conservation and preservation of natural resources. These can be resolved or minimized through adequate planning. The key question at this point, of course, is what kind of planning can be carried out for the Espiritu Santo River Basin within the limits of existing administrative and political schemes, and the scale on which that planning can be carried out.

THE ESPIRITU SANTO RIVER BASIN AS A UNIT OF ANALYSIS

Given the limited size of Puerto Rico's river basins, the centralization of the Island's planning structure, and the very restricted powers and funds of the municipalities in which these river basins lie, the planning necessary to guide their development while protecting and conserving their delicate ecosystems can be carried out by using the river basins as units of analysis rather than planning subjects. Within this concept, several river basins together could constitute a single subject of planning.

The primary purpose of establishing the river basin as a unit of analysis is to facilitate the management of the natural resources, including the environment, contained within the basin. The Espiritu Santo River Basin is fortunate in that it already is being used as a unit of analysis, in the sense that it has been the subject of continuing study by scientists at the Center for Energy and Environmental Research. As a result, the specific studies necessary for resources management planning in the river basin have been, and are being, carried out.

Carried out. In order to achieve a working partnership between this scientific research effort and the planning process, the CEBR study should extend from the identification of the river basin's resources, their characteristics and composition, to a delineation of the kinds of dangers to which each is subject. In other words, the study effort should provide planners with precise information regarding the limits of tolerance of the various natural resources contained within the river basin, and the degree to which those limits have been reached in each case. It should identify and classify the sources of environmental damage and pollution affecting the river basin, and provide alternatives for the management, use, conservation, and development of the natural resources contained within the river basin.

Characteristics of the Espiritu Santo River Basin

The Espiritu Santo River Basin is ideally suited to its role as a unit of analysis for resources management planning on an island-wide basis. Within its relatively small geographic extension, the river basin offers a vast variety of social, economic, ecological, and environmental characteristics that provide planners with a microcosm of the entire island. In effect, it provides the social scientist with a giant test tube in a natural setting laboratory. The implications of this condition in terms of public policy should not be underestimated. The river basin has an additional advantage in that it is wholly contained within a single political entity: the municipality of Rio Grande.

In specific terms, the river basin contains the following elements:

1. Two of the island’s most important forest reserves, El Yunque and Rio Verde, are partially within and adjacent to the river basin.

2. The highest precipitation rate in Puerto Rico and the physiographical characteristics necessary for the damming of reservoirs.

3. A high incidence of bilharzia in the Espiritu Santo River.

4. Good agricultural land.

5. A high level of industrial development.

6. A rapid

The urbanization process has led to a significant increase in the region's population along with notable migration patterns. This region is home to marine and terrestrial ecosystems of unique ecological value. It is located in close proximity to metropolitan San Juan; the river basin is only 16 miles from the capital. There are good access routes, with a major highway dividing the river basin into two zones. The area witnesses a high rate of both public and private construction activity. It is one of the highest risk flood-prone areas on the Island. There is a high degree of tourism development adjacent to the river basin; at least one hotel is currently operating in the municipality of Rio Grande, and boating excursions down the river are offered.

All of these characteristics make the Espiritu Santo River Basin ideal as a unit for resource management planning. It can be viewed as a scale model of the Island for the scientific research being conducted by the CEER. Additionally, it provides the conditions for all manner of analysis and simulation at the theoretical level.

As mentioned above, the value of such a microcosm in terms of public policymaking is enormous. The case of the Willamette River Basin in Oregon provides an excellent example of the valuable lessons to be learned from such an approach. The U.S. Geological Survey recently completed an extensive evaluation of that river basin, in which the chief finding was that the indiscriminate application of water treatment will not ensure compliance with the water quality standards established in federal legislation. This finding implies that the establishment of rigid standards and regulations on a nationwide basis could result in unnecessary costs in some cases and failure to satisfy those standards in others. The USGS also found that the information and data obtained through existing monitoring systems are inadequate for pinpointing the critical interrelationships that control water quality problems in rivers. The study concluded that intensive research is needed in this area.

Evaluation of key conditions and problems is necessary in order to make decisions regarding river basin management. The implications of this study for resource management, of course, are that studies must be carried out in specific areas before any single project can be implemented. The socioeconomic structures of rivers and their drainage basins are dynamic in nature, and the processes that affect them are the result of the interaction of natural factors complicated by human activities, and the changes these activities produce. This interaction creates problems at the local level that, once they are thoroughly analyzed, often can be resolved at the local level.

The following sections examine how the river basin as a unit of analysis can function in a practical way with specific reference to the Espiritu Santo River Basin, and suggests some schemes of intervention in the planning process for a more effective management of the basin's natural resources.

DEFINITION OF THE RIVER BASIN AS A UNIT OF ANALYSIS FOR PLANNING

First of all, the flow of decisions arising from the different decisional units outside the river basin, that have an impact on its natural and energy resources, must be recognized. This process can be demonstrated graphically as follows: policies regarding land development and economic development strategy, as well as the desire on the part of private enterprise to carry out its development projects, all have their impact on the river basin and its natural resources.

A dramatic example of this process was provided on the very day the seminar on river basin planning was being held, when the government granted approval for a vast residential-tourism complex in Rio Grande. One might well ask if this decision, with all of its implications for the public interest, would have been taken if studies regarding the river basin's ecological, social and economic systems had been conducted and their results made known, and if organized special interest groups dedicated to the protection.

The conservation of the river basin's natural resources and environment has existed.

The sad truth at present is that the Espiritu Santo River Basin lacks the tools and mechanisms to protect itself from decisions taken outside the river basin that affect it in fundamental ways. As the area contains a series of natural resources and features, classifiable as extrasystemic areas of interest, it attracts outside decision-making units. With improved transportation and the development of nearby employment centers, we can expect these decisions to proliferate and intensify the urbanization process of Rio Grande.

The above perception of the situation faced by the Espiritu Santo River Basin should not be interpreted as a pessimistic view of its planning possibilities. Instead, it provides a realistic framework within which we can seek pragmatic solutions to the problem within the context of Puerto Rico's existing planning structure.

As previously mentioned, Puerto Rico's planning system is centralized and does not support the type of independent, regional development exemplified by the TVA and other administrative schemes devised elsewhere to develop and manage a river basin.

However, the purpose of this paper is not to suggest ways of changing the island's planning system or the available planning instruments, but to demonstrate how the methodological approach can be improved within the existing system at the river basin level, so that these planning instruments function effectively.

SCHEMES OF INTERVENTION IN THE PLANNING PROCESS

The focus of the planning effort for the Espiritu Santo River Basin should be advocacy planning rather than comprehensive planning. Within this concept, two basic strategies can be adopted:

1. Data and information gathered by the CEER in its research efforts, including information regarding the tolerance levels of the river basin's natural resources, should be made available to planners at the central level, to ensure that the research is utilized effectively.

Findings are taken into consideration in the planning process. Secondly, public awareness should be developed in the river basin area, regarding the basin's natural riches and potential consequences if they are not protected. The first step in implementing these strategies is to identify the major actors in the decision-making process and in the execution of the policies and decisions that are established.

Essentially, these major forces fall into three distinct groups:

1. The public agencies, both commonwealth and federal, that are involved with the plans, programs, and projects that affect the Espiritu Santo River Basin.

2. The sectors within private industry that currently have development projects in the area or may have them in the future.

3. Interested pressure groups, such as social and religious organizations, civic clubs, environmentalists, ad hoc groups, and other associations of citizens with the interest and desire to protect and preserve the Espiritu Santo River Basin within the development process.

Once these three major forces have been identified, the final step is to determine how each aspect of the environment - the social, economic, and physical - affects each of these groups and how they, in turn, affect the environment.

This identification will produce the information necessary to determine how to reach each group, what data is needed by each, and how each can be involved in the goal of protecting and preserving the natural and energy resources of the Espiritu Santo River Basin.

The process functions in the form of a chain: The research produces data and information, leading to public awareness and pressure, producing greater care in the decision-making process, which leads to a reduction of environmental damage. This pragmatic solution, the use of advocacy planning in the Espiritu Santo River Basin, can be carried out effectively within the existing planning system and can produce great benefits for the area in terms of the protection and preservation of its precious resources.

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