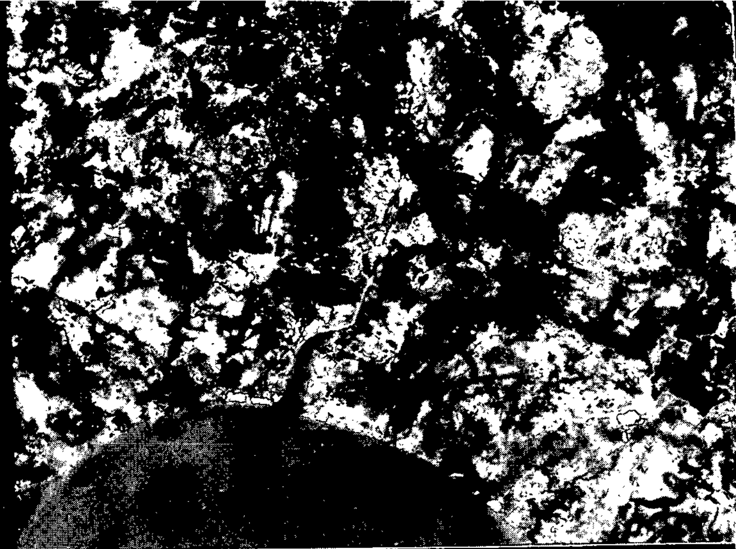

AN INTEGRATED NATURAL RESOURCES EVALUATION

PAN AMERICAN UNION
WASHINGTON D.C.

977

SURVEY FOR THE DEVELOPMENT OF THE GUAYAS RIVER

BASIN OF ECUADOR

An Integrated Natural Resource Evaluation

Prepared in the Department of Economic Affairs of the

PAN AMERICAN UNION

General Secretariat, Organization of American States

WASHINGTON, D.C.

1964

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ABSTRACT

In 1962, a request was made by the Government of Ecuador to the General Secretariat of the Organization of American States for technical assistance in surveying and assessing Ecuador's natural resources, so as to provide an informational base for development planning and programming. The request was responded to by the Natural Resources Unit of the OAS' Department of Economic Affairs. Specifically, the technical assistance took the form of two missions: (1) an inventory and evaluation of the information basic to resource development, and of the programs and capabilities of Ecuadorian institutions concerned with investigations, mapping and development in this sector, followed by (2) an integrated reconnaissance study of the natural resources of the Guayas River Basin on Ecuador's Pacific coast. The findings of both technical assistance missions are included in this report.

The National Inventory

The national inventory and evaluation sought to determine the informational needs for national resource development planning and the extent to which Ecuadorian institutions and technical personnel could fill these requirements. An inventory was made of available aerial photographs, topographic, geologic, soils, vegetation and land use maps and studies, and the institutional programs and personnel for data collection and mapping were reviewed and evaluated. It was found that there was insufficient data for effectively planning and programming resources development; important types of mapping did not exist and available topical maps and studies were too generalized for the purposes of the development planner. Furthermore, the institutional and technical capabilities were so limited as to preclude rapid data acquisition and analysis on a national scale for planning and programming resource development.

The substantial time and cost required to obtain the needed information was not judged to be commensurate with the stated desirability of planning and executing development programs in the shortest time possible. In consultation with Ecuadorian authorities, the decision was made to concentrate study efforts on a region within the country with good resource potentials and development possibilities. The Guayas River Basin was selected and the OAS entered into an agreement with the Ecuadorian government to undertake an integrated evaluation of the Basin's natural resources in order to provide a point of departure for planning and programming regional development.

The Integrated Evaluation of the Guayas River Basin.

In mid-1963, an OAS-supervised technical team consisting of a geographer, a forester, an irrigation engineer, a soils surveyor and a geologist completed a six-month reconnaissance of the climate, geology, geomorphology, water resources and irrigation systems, soils, forests, land use, and population distribution in the Guayas River Basin and its watershed. Data obtained from aerial photographs and field surveys, as well as from existing studies and maps, were compiled and analyzed. Maps of geology, soils, land use and vegetation, and population distribution were compiled at a scale of 1:500,000. Smaller scale maps depicting monthly and annual rainfall distribution, ecologic formations and geomorphology were also prepared. A synthesis of the relative values of the different physical resources was accomplished by cartographic superimposition. For this purpose an analytic map depicting differing values of terrain conditions and soils, surface water and forest potentials was compiled. This map constituted a base for weighing the importance to development of climate, population distribution, land use and the existing transportation network.

A map depicting development regions was then constructed which synthesizes the assessment of development potentials and problems as influenced by the various factors taken into consideration in the analysis.

The Guayas River Basin

The 33,640 square kilometer watershed of the Guayas River consists of a broad north-south trending basin whose extensive southern flood plain merges with an undulating and partially dissected landscape in the upper river Basin. The Basin is enclosed by the elevated and steep Andean Cordillera to the east, and lower, dissected ranges to the north and west.

The very humid tropical climate and erosional processes acting upon the basic igneous and volcanic rocks of the Andean slopes have provided the Guayas plain with approximately 9,500 square kilometers of fertile alluvial soils, whose agricultural capabilities are diminished in varying degrees by seasonal drought, flooding and poor drainage over some 6,000 square kilometers in the dry tropical southern flood plain. The numerous tributary streams with headwaters in the humid Andean front, however, offer good possibilities for irrigation development where they traverse the southern flood plain; also, the deep sediments found here are judged to have abundant groundwater reserves. Principal economic crops of the southern flood plain are sugar cane, bananas, cacao, cotton and rice; castor beans, citrus and other fruits are also cultivated. Present irrigation is newly developed and confined to two small areas west of the port city of Guayaquil. Irrigation distribution networks have been found to be incomplete and inadequate, resulting in inefficient water use. Generally speaking, a low level of technology is employed in agricultural production throughout the southern flood plain. Rural population is moderately dense, tending to concentrate along the road and water routes leading to Guayaquil.

The northern sector of the Guayas Basin has considerable areas of well drained, fertile volcanic soils which receive adequate rainfall and are not subject to seasonal drought. Other soils are less fertile owing to parent material origin and the leaching effects of high rainfall. Evergreen and deciduous broadleaf forests found in this more sparsely populated portion of the upper Guayas Basin occupy an estimated 6,000 square kilometers and have timber volumes ranging from 20,000 to 40,000 board feet per hectare on well drained sites. Among the commercial species found is balsa, which has been heavily exploited in the more accessible zones. Roughly 3,500 square kilometers of forested or partially settled lands between Quevedo and Santo Domingo de los Colorados have excellent soils and very good settlement potential.

On the forested tropical hills and dissected ranges of the northwest, continuous timber exploitation is possible, but agricultural development is made less feasible by broken terrain, poor soils and high rainfall. In the general vicinity of Quevedo and Balzar some 2,400 square kilometers of land are in the process of settlement and agricultural development. Bananas are the principal crop; cacao is grown to a lesser extent. Ecologic conditions favor the cultivation of African oil palm. These lands could absorb perhaps twice as many rural inhabitants through colonization.

The lower Andean slopes offer diverse development possibilities: perennial agriculture, forest exploitation, multi-purpose hydroelectric projects and mining. Steep slopes and high rainfall hinder certain phases of development and create problems in soil conservation and road construction and maintenance.

Principal Resource Potentials and Problems to Development

The principal natural resources of the Guayas Basin are its fertile soils, abundant ground and surface water and tropical forests. Metallic minerals are of limited occurrence and oil, gas or coal have not been discovered nor do there exist geologic reasons for believing they exist. Future development will therefore be primarily in forest exploitation and agriculture, both irrigated and unirrigated. A major physical problem hindering the development of these resources is the nature of the lowlying, flat terrain to the south which causes poor soils drainage and flooding and creates difficulties with irrigation and drainage measures. Along the Andean slopes the feasibility of water impoundment is reduced by steepness of stream gradient and narrowness of canyons. Conversely the lack of gradient and terrain features favorable to water impoundment in the Guayas plain limit possibilities of reservoir construction. In the east central portion of the Guayas plain, which could benefit greatly by irrigation, gravity conduction of irrigation water is made difficult by considerable local relief in areas with good soils and surface water. Physical problems affecting forest exploitation are inaccessibility, poorly drained sites with no significant volumes of timber and rugged terrain problematical to the extraction of logs.

Guidelines to Future Development

The composite evaluation of the resource base and population distribution, land use patterns, and transportation nets resulted in the definition and demarcation of three major development regions with a total area of 21,443 square kilometers, which are distinguished by different development problems and potentials.

Agricultural Intensification Development Region: The already settled and moderately densely populated southern flood plain with an area of 11,361 square kilometers, 6,000 of which have inherently fertile soils. Agricultural production could be increased through local flood control and drainage measures, irrigation and improved agricultural technology.

Colonization Development Region: The partially settled central northern portion of the Basin covering 7,672 square kilometers with excellent soils and forest resources. This region could support a greater number of agriculturalists and could best be developed through planned colonization, complemented by mineral and forest exploitation activities.

Forest Development Region: The 2,410 square kilometers of evergreen and deciduous tropical forest in the upper northwest Basin encountered in a hilly and dissected landscape with relatively inferior clay soils. This zone has low agricultural potential but could be made productive through properly managed, sustained-yield timber exploitation. This activity could complement the agricultural development of the adjacent colonization region.

Smaller subregions within these large development regions were identified and demarcated on the basis of differences in their resources base, type and severity of development problems, and population distribution. Selected subregions with especially high potential for development through irrigation and colonization were assigned high priorities for future development. Areas within the Guayas watershed with marginal potentials, totalling 13,000 square kilometers, were eliminated from further immediate consideration due to their unfavorable climates and poor resource base, in places strained by a very dense rural population.

Recomended Program of Investigation for the Guayas River Basin

Based upon the reconnaissance investigations and analyses, a two-year $1.3 million program of further investigation, engineering, and planning activity has been formulated. The several objectives of the programs are:

(1) to provide within the shortest time possible information useful for project planning and financing in selected regions with high development potentials;

(2) to define with greater precision the limitations of regions with lesser potentials so as to evaluate the justification of higher development costs;

(3) to provide basic data of sufficient detail and scope to be of use in planning and implementing programs for the development of the entire Guayas River Basin; and

(4) to train Ecuadorian personnel in the technical and administrative fields needed to carry out further investigation and to plan and implement development in the Guayas Basin.

The basic orientation of the recommended program of investigations is toward planned development. The different components of the program are formulated in terms of development planning needs and are justifiable on that basis. In addition, the necessity to obtain international financing for development implementation has been anticipated, and the investigations that are recommended were conceived so as to satisfy the requirements for data needed to formulate development loan proposals.

Within two of the major development regions, the Agricultural Intensification Region and the Colonization Region, investigations in the subregions with the highest potentials for development are recommended which will furnish data for the planning and justification of irrigation and colonization projects. For the Forestry Development Region, surveys are recommended which will lead to the formulation of forest management policies and plans for sustained yield logging. In addition, recommendations are made for more detailed surveys of the entire Basin as regards use, land tenure and land capabilities to provide a point of departure for Basin-wide planning and to furnish a factual base for formulating technical assistance and credit programs designed to increase production and promote better land use and conservation.

Preface

One of the principal aims of the Alliance for Progress is to provide the basis for, and to stimulate, intelligent development planning. An absolute prerequisite to such planning, and to development itself, is a sound knowledge of the natural resources of a country, their present use, and the conditions of the physical environment that affect development. In recognition of this, the Charter of Punta del Este directs that the participating Latin American countries should, in addition to creating and strengthening machinery for long-term development programming, immediately increase their efforts to implement specific projects which are designed to survey and assess natural resources /Charter of Punta del Este, Title II, Chapter III, Section 2.b.(4)/.

Requests for technical assistance in natural resource surveys have been received from member countries by the General Secretariat of the Organization of American States (OAS) and have been acted upon in accordance with the provisions of Title II, Chapter IV, Section 3.a and .b of the Charter. The present report is the result of the technical assistance provided by the OAS, through the Unit of Natural Resources of the Department of Economic Affairs, in response to the first of such requests received from the Government of Ecuador. In a sense this report constitutes a pilot program in technical assistance from which has evolved a methodology that appears to have application in servicing future requests for assistance in natural resource surveys.

Basically, the technical assistance provided by the OAS to the Government of Ecuador involved two consecutive missions to that country, the first in July 1962, and the second in July 1963. The findings of both missions are here presented. The original assistance provided in 1962 grew out of a request from the National Planning Board of Ecuador for assistance in the preparation of the terms of reference for a national program of natural resource investigations designed to remedy deficiencies in basic data needed for planing over-all development and executing specific projects. In July 1962, the OAS sent a team of technicians headed by Kirk P. Rodgers, natural resource specialist of the Department of Economic Affairs. The team included Dr. Ellis Knox, soil scientist and Benjamin Munroe, photogrammetrist of AID. Working closely with the mission was Dr. Gerardo Canet, OAS Coordinator for Technical Assistance in Ecuador. The basic findings of this mission are found in the first chapter of the present report; however, much of the information has been updated by drawing upon the later work of the OAS in Ecuador.

In April 1963, the National Planning Board requested that the OAS carry out reconnaissance level investigations of the natural resources of the Guayas Basin in order to delineate areas of high potential for development which justified further study, and to prepare the terms of reference for such investigations and mapping as required for promoting development and implementing specific projects.

The second OAS mission arrived in Ecuador in mid-July 1963. It was an interdisciplinary team composed of John W. Brown, soil scientist from the U.S. Department of Agriculture, Robert H. Morris, geologist from the U.S. Geological Survey, Felipe Borelli, irrigation engineer, Verdell G. Erickson, forester from the U.S. Forest Service, Kip Willett, cartographer, and Dr. Richard P. Momsen Jr., economic geographer. Dr. Momsen acted as team leader in the field, and Mr. Rodgers of the OAS served as coordinator of the mission.

To carry out the second phase of assistance to the Government of Ecuador, part of the necessary funds were provided by the U.S. Agency for International Development to the Ecuadorean Planning Board, which in turn signed a contract with the Organization of American States on June 28, 1963, for carrying out the required technical assistance.1/ The Ministerio de Fomento of Ecuador provided logistic support to the mission while counterpart technicians were supplied by the Caja Nacional de Riego, the Junta Nacional de Planificación, and several departments of the Ministerio de Fomento.

The present report was prepared by Kirk P. Rodgers and Peter H. Freeman under the direction of Dr. Wolfram U. Drewes, Chief of the Natural Resources Unit, Department of Economic Affairs. The maps and graphics were compiled and drafted by the cartographic staff of the Natural Resources Unit under the direction of Harold L. Peacock, and editorial services were provided by the Publications and Documents Unit of the Department of Economic Affairs under the direction of Marc Yaffe.

1. See Appendix A.

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Introduction

The present report comprises in essence the results of two missions to Ecuador, the organizational aspects of which have been described in the preface. In substance, the principal undertaking of the first OAS mission was a thorough inventory of existing natural resource data in Ecuador and an evaluation of the regional needs for resource investigations in support of development programs. The basic conclusion reached by the mission was that the Government of Ecuador should initially concentrate its efforts in natural resource studies in the promising Guayas River Basin, rather than attempting a national program of resource investigations. The purpose of such studies should be to produce data concerning natural resources useful for development planning and determination of project feasibility, rather than a non-specific classification of the resources of the Basin. It was felt that so-called natural resource inventories are, in fact, frequently wasteful of scarce human and financial resources and produce an overabundance of data which is quickly out of date in a developing country. A better approach seemed to be the preliminary identification of resource development potentials and the orientation of resource studies to the determination of project feasibility. The scarcity of information--even at a reconnaissance level--about the Guayas Basin, however, precluded the accurate identification of these potentials and thus prevented the formulation and justification of detailed plans for mapping and data collection.

The objectives of the second mission--the natural resources evaluation of the Guayas Basin--are set forth in a contract between the Ecuadorean Junta Nacional de Planificación y Coordinación Económica and the Secretariat of the Organization of American States.1/ They are:

(a) To identify areas suitable for further development and the physical problems which curtail such development,

(b) To prepare the terms of reference for loan applications for investigations of natural resources, and

(c) To prepare the terms of reference for certain priority projects for natural resource development.

This last objective was intended to speed the initiation of specific development projects within the Guayas Basin.

A program of integrated investigations was formulated which was carried out by a team of technicians representing the disciplines of geology, forestry, soils science, irrigation engineering, demography and geography. The team

1. Appendix A, Article I, A 2.

leader was the geographer. These technicians utilized 1:60,000 scale aerial photographs made available by the Ecuadorean government, available maps, studies and unpublished data pertinent to the Guayas Basin and carried out field investigations. Reconnaissance type data pertaining to geology, geomorphology, soils, land use, and vegetation obtained from aerial photographs and in the field were compiled at scales of 1:250,000 and 1:500,000. Census information was compiled on a 1:250,000 base to indicate population distribution. Rainfall data was also compiled and depicted on a small scale cartographic base.

Mapping accuracy was restricted to the sixty percent of the basin having 1:60,000 aerial photographic coverage, which corresponds roughly to the southern and middle portions of the Guayas Basin. Photointerpretations were verified by field checks, and for inaccessible areas without aerial photographs, low level aerial reconnaissances were employed. Further comments on methods and limitations to accuracy are given in the chapters which follow, dealing with the surveys of specific resources. Techniques of factorial and composite analyses used to define high potential sub-regions are also described in the body of this report.

Field work began in July 1963, and was completed by the following September. Analysis and synthesis of data were terminated in December, 1963, and the compilation and publication of maps and graphics was terminated in April of 1964, at which time the results of the Guayas Basin survey were presented to the Government of Ecuador.

The National Inventory

CHAPTER I

Inventory and Evaluation of Existing Natural Resource Data, Agencies and Training Facilities in Ecuador

Although by 1963 Ecuador had made great strides in accelerating its national program of basic mapping and acquisition of data on natural resources, the nation was at the time of this project still far from possessing the minimum knowledge of its physical conditions, natural resources and present land use, which are necessary for effective long-range planning and, more important, for the selection, preparation and economic justification of specific development projects.

Clearly it was urgent that Ecuador undertake programs for the acquisition of needed data and provide at the same time for the build-up of its institutions in these fields. Before initiating such programs, however, it was judged necessary to carefully inventory existing data and determine the capabilities of Ecuador's institutions and training facilities.

The first OAS mission to Ecuador therefore had the following objectives:

(1) Determination of the status of existing data pertaining to natural resources and physical conditions in Ecuador;

(2) Evaluation of the agencies and institutions engaged in natural resource investigations and their plans for future work; and

(3) Evaluation of the local training facilities available for preparing technicians in the natural resources fields.

The procedure employed in this initial phase of the investigations involved careful indexing of all aerial photography and mapping of topography, soils, geology, vegetation, ecology, land use and land capability available in the country and portrayal of this data on index maps.1/ Published hydrologic and meteorologic data was also reviewed and bibliographies were prepared of the literature pertaining to all of the above subjects. Simultaneously, a team of specialists carried out extensive interviews with Ecuadorean government agencies, universities and international organizations working in the country. Information was obtained about plans for future programs as well as present operations. Following are the findings of the mission in each of the fields selected.

1. The map indexes compiled during the mission will be published in 1964 by the OAS under the title, "Annotated Index of Aerial Photographic Coverage and Mapping of Topography and Natural Resources--Ecuador." This is one of a series of such annotated indexes covering all of the Latin American member countries of the OAS.

Aerial Photography

More than 65 percent of Ecuador's total area has to the present been covered by aerial photography, which dates back as far as 1940 and includes great ranges of scales, types and qualities. There has been a great deal of duplication of photographic coverage, due in part to the poor quality of older photography, however, some of this duplicated material is useful for comparative studies of land use and other cultural features that have undergone rapid changes. And while only a small percentage of this photography is suitable for the topographic mapping program of the Instituto Geográfico Militar (IGM), nearly all of it has value for a program of photographic interpretation and natural resource study and mapping. Most of this photography is presently held by the Instituto Geográfico Militar.

1. Trimetrogon Photography

Between 1943 and 1945 a large amount of trimetrogon aerial photography at a scale of 1:40,000 was taken by the United States Air Force in collaboration with the Ecuadorean government. This coverage includes portions of the Coast and Sierra region of the country, as well as scattered coverage along the Brazilian border in eastern Ecuador.

2. Vertical Photography

In 1955-56, Hycon Aerial Surveys, Inc., under contract with the U.S. Army Map Service and in collaboration with the Ecuadorean government, photographed a large section of the Sierra region from Ibarra in the north to Cuenca in the south. Multiple cameras were used in the aircraft, one installation containing a standard six-inch lens camera and the other a split vertical installation with two twelve-inch lenses. Together these camera installations provided for simultaneous photographic coverage at two different scales. The flying altitude was approximately 30,000 feet, but because of the elevation of the Sierra region the actual scale of the photography is approximately 1:45,000 and 1:25,000.

In 1959-60, two blocks of photography at a scale of 1:40,000 were flown for oil companies, one covering the central portion of the province of Manabi and the other covering the Santa Elena Peninsula. A large block of photography (1:40,000) of the tropical lowland of eastern Ecuador taken by Shell Oil Company in 1940-44 is also worthy of note. Copies are held by the IGM, although the original film was destroyed by a fire in the Netherlands during World War II.

By far the most important aerial photographic coverage of the country, is that taken this year by the U.S. Air Force in cooperation with the IGM and the Inter-American Geodetic Survey (IAGS). Unfortunately, unfavorable flying weather prevented completion of the project and the acquisition of much needed coverage in the Coastal area, notably the central part of the Guayas River Basin. This program of small scale photography (1:60,000) did cover some 21 percent of the country, however, producing a large number of photo strips in the Sierra and a substantial block in the western part of the Coastal region. Plans call for complete coverage of the Coast and the Sierra in four years. This photography is being used for the 1:50,000 topographic mapping program of the IGM.

Topographic Mapping and Geodetic Control

1. Status of Topographic Mapping and Geodetic Control

To date, approximately 15 percent of Ecuador has been covered by topographic maps and map compilations, but only about 10 percent has actually been published, and less than 5 percent in the form of high quality maps. A topograhic mapping program of the Sierra begun in 1928, using a system of terrestrial photography for map construction yielded 85 printed maps at 1:25,000, eight at 1:20,000, and an additional 170 maps which were compiled but not printed. A cooperative program with the IAGS was begun in 1947, with the first years devoted to establishing geodetic control. As a result of this continuing program, first order triangulation and high precision leveling was completed in the populated coastal and highland areas. Aerial photography for topographic mapping was begun in 1956 with the Hycon flights.

By early 1964, 19 topographic sheets at a scale of 1:50,000 had been produced under the IGM-IAGS cooperative program and nine more were in the final map drafting stage. During 1964-65, the IGM is scheduled to complete compilation of 36 sheets at 1:50,000. Stereo compilation of 13,120 Km^2 has been completed for the first priority area west of 71°30'. This is approximately seven percent of the total area to be mapped.

On October 19, 1961, the Government of Ecuador signed a $1.8 million loan agreement with the Development Loan Fund (DLF) to greatly intensify the national topographic mapping program. This loan was implemented in September 1962. By 1963, lists had been submitted for purchase of equipment for the photographic library, surveying field parties, and a reproduction plant, as well as orders for photogrammetric equipment, vehicles and other supplies. The $1.8 million loan also provided for a new building for the IGM,2/ a large amount of new equipment, an expanded general budget, and a provision of $300,000 for contracting private aerial photographic firms to take additional photography to accelerate the program.

2. Evaluation of the Capabilities of the Instituto Geografico Militar

The IGM is a military organization with a supervisory force composed of military personnel. The technicians, except for women, are civilians with military status. As of 1964, IGM personnel numbered some 215, made up of 47 officers, 154 enlisted and 14 civilian draftsmen. It is planned to gradually increase this number to about 275. The IGM operates on government funds, although it occasionally does printing for other government agencies on a commercial basis.

2. The original sum provided for the mapping plant and furniture was $300,000. As the plans left the drafting boards the building was estimated to cost $750,000. Final plans for a plant of $535,000 for the main block were approved in 1964.

Personnel training

With the assistance of IAGS, the IGM has been carrying out what appears to be an excellent personnel training program in preparation for future needs. The first round of training was completed in 1963 by a group of technicians who took a special cartography course given by the U.S. Army's School of Engineering. Of the 14 students who graduated, five were to receive further training in basic photogrammetry, and the remainder were to specialize in geodesy, astronomy, field classification and topography.

Existing bottlenecks in the production of topographic maps

The main bottleneck at present is the lack of photographic coverage of reasonably extensive areas suitable for the production of maps. The gap areas present an obstacle to economically undertaking supplemental geodetic control and field classification. The lack of coverage also prevents the planning of reasonable programs based on a priority order of execution. In early 1964 there was only enough high altitude photography for nine more months of field work.

Other limitations to the IGM's production capacity are their extremely inadequate facilities and cramped quarters. The new building that is planned should alleviate this situation, but the transition period promises to be difficult.

If the bottleneck brought on by a lack of photo coverage is alleviated, production capacities would still be restricted to the speed of operations of the triangulation and compilation phases, which suffer from lack of instruments. It is hoped that the delivery of new equipment financed under the DLF loan will break this potential bottleneck.

Plans for future work

IGM's production schedule for the future is optimistic. It is estimated that 90 percent of the 1:50,000 scale mapping will be complete within five years--provided the photography is obtained at a sufficiently rapid rate. It is estimated that acquisition of the remaining 10 percent, for the Esmeraldas area, might require many years because of unfavorable climatic conditions. Plans for larger scale mapping of the jungle area to the east of the Andes had not yet been formulated, but plans for establishing basic control in this area were being studied.

Estimates of production capacity

The preparation of accurate topographic maps is an exceedingly complex process requiring careful coordination of many steps and considerable time in order to achieve the specified levels of accuracy.[3] The many steps in the process are intimately linked, with each new one dependent upon those preceding. Each phase of the process, furthermore, requires well-trained and thoroughly skilled personnel working with precision equipment, in order to meet the established standards of accuracy. If there is a slowdown or bottleneck at any one stage in the operation, the whole program can be retarded. Thus, although it has been estimated by the IGM that only five years will be required to complete 90 percent of the 1:50,000 scale mapping, it is apparent that the process is extremely vulnerable to delays.

The mission attempted to realistically gauge what the production rate of the program is likely to be once it gets underway with full utilization of the funds from the DLF loan, and in the interim period. The estimates have been based upon experience with similar programs in other countries and on evaluation of specific conditions in Ecuador. It would seem certain from all information available that once the DLF-supported program is fully underway, following construction of the new building, installation of equipment, and extensive training, the production rate at best might approach 75 sheets per year.

In the interim period, which could last from 18 months to two years, a production rate of from 18 to 20 sheets per year seems likely. Therefore, in total it appears that a minimum of from seven to 10 years will be required to complete the full program of 415 sheets at 1:50,000 and 50-plus sheets at 1:100,000. It is, of course, assumed that no major delays in the acquisition of aerial photography are encountered.

While it would be ideal to have the 1:50,000 and 1:100,000 topographic sheets available on a broad scale to provide the mapping base for investigations of soils, geology, forestry, land use, etc., to wait many years for such base material before beginning such investigations would not be in Ecuador's best interests. Semicontrolled photo-mosaics are considered to be a sufficient base for the portrayal of such information in the absence of topograhic maps. While the IGM appears to have the capability to prepare such mosaics, the 1964 work force was not judged to be sufficient for the additional work load. To augment the work force, financial assistance would probably be required since there is no provision for photomosaic construction in IGM's current program.

3. The steps or sequence of operations in making a map, provided the basic horizontal and vertical control is available, are as follow: a) photography, b) supplemental geodetic control, c) preparation and stereotriangulation, d) field classification, e) compilation, f) scribing or drafting, g) reproduction.

Steps (b) and (d) may be performed simultaneously and editing and/or quality control is required in steps (e), (f), and (g).

Geology 4/

1. Status of Geologic Mapping

Up to mid-1964, geologic mapping in Ecuador was restricted mainly to small-scale reconnaissance-type mapping carried out by foreign geologists, and generalized maps released by various oil companies.

In 1950, Walter Sauer, a German geologist who taught for a number of years at the Universidad Central del Ecuador (Quito), published a geologic map covering most of the country, and in 1957 he issued a report which became a basic geologic reference work for Ecuador. The map at a scale of 1:1,500,000, is basically a compilation of geologic mapping done by the International Petroleum Company in the Coastal region, by the Shell, Sinclair, and Wason oil companies in the Oriente region and Sauer's own geologic mapping of the Andean region.5/ It provides a good reconnaissance picture of the geology of Ecuador although it has been superceded in part by recent work. Also in 1950, Sauer published a geologic quadrangle map of Quito at 1:25,000.

Substantial unpublished geologic mapping was found to be held by foreign oil companies; it is unavailable to the public, however, except under special circumstances. A few detailed maps and reports of mining districts and individual mines are archived in government files or are available in published reports.

In summary, it was found that the knowledge of Ecuadorean geology is exceedingly sketchy and that no geologic mapping program exists to remedy this deficiency.

2. Evaluation of Existing Agencies

Until 1963, the principal government agency in the field of geology in Ecuador was the Sección Geológica y de Prospección of the Dirección de Minas e Hidrocarburos. This agency was responsible for the preparation of studies and reports required by law in relation to mineral and petroleum concessions. It also studied production, consumption, and export of mineral products and petroleum for taxation purposes. While it had the authority to perform analyses of minerals and to prepare mineral and petroleum maps, its actual work was restricted to the granting and recording of mineral and petroleum concessions and the preparation of statistics on mineral production. In June 1963, the Departamento Nacional de Geología was created within the Ministerio de Fomento. This agency has now assumed the major responsibility for geologic investigations but, to date, still has only two professional geologists on its staff. The functions of production control and statistics are charged to a separate section in the Dirección General de Minas e Hidrocarburos.

4. In the evaluation of geologic data and institutions in Ecuador frequent use has been made of the report: Geology in Ecuador - A Review, George E. Erickson, USAID, July 22, 1961. It is cited only where directly quoted.

5. Ibid., p. 271.

3. Status of Geologic Training

In Ecuador, four universities offer courses in geology: Universidad Central del Ecuador (Quito), Escuela Politécnica Nacional de Quito, Universidad de Cuenca, and the Escuela Politécnica del Litoral (Guayaquil). In general, the courses offered appear to give the students sufficient background for understanding more advanced material.

Of the four universities, the Universidad Central del Ecuador seems to offer the best geologic training program. It has several professors teaching such subjects as mineralogy, petrography, general geology and applied geology, and has a good collection of rocks and minerals, laboratory equipment for mineral analysis, and a small but adequate library. A School of Mining and Geology was very recently opened in the Faculty of Chemistry of this university, and future plans call for the training of professional geologists, with the first to be graduated in 1968.

4. Status of Engineering Geology

Training in engineering geology, with particular emphasis on planning and development of highways and the study of foundation conditions in areas subject to seismic movement, was found lacking. As of 1964, there was no provision for this type of investigation in the country and no agencies working in the field. In 1963, the Ministerio de Obras Públicas requested that a United States technician be assigned for a 6-week study of landslides along the new Quito-Santo Domingo de los Colorados highway. Mr. William L. Eagers was appointed by the U.S. Bureau of Public Roads to make this study during the fall of 1963, and his report suggests certain technical solutions to existing landslide problems. The long-term problems related to engineering geology, however, have not been confronted.

It would be very desirable for Ecuador to establish an agency charged with these matters. There are two possibilities: (1) that the recently created Departamento Nacional de Geología (DNG) in the Ministerio de Fomento build up a branch of engineering geology to act as consultants to other government agencies; or (2) that the Ministerio de Obras Públicas create a geology department to study roadways. For each of the ministries there are certain advantages in creating its own engineering geology branch. Such a branch within the DNG could not only furnish basic data for highway construction but also for proposed dam sites, railroad rights-of-way, and any large buildings that might be affected by earthquakes or other geologic phenomena. The branch would also be in a more advantageous position to interchange and assimilate the geologic data of other geologists and branches of the DNG. The decision concerning the establishment of an engineering geology branch in either Ministry, however, should be based on further study.

5. Plans for Future Work in Geology and Mineral Resources

Several international study teams have in recent years reviewed mining activity and mineral deposits in Ecuador. In 1958, the country was studied by the Misión Alemana-Ecuatoriana; in 1959 by the Japanese-Ecuadorian mission;

and in 1961 by a United States AID team. Reports prepared by these missions and various mining companies, which are on file in the Ministerio de Fomento, summarize data on known mineral reserves and mineral potentials in Ecuador.

As a result of these and other international team studies, the United Nations undertook to prepare, in June 1963, a three-and-a-half year development plan. The cost of preparing the plan, some $1,400,000, is being borne by the United Nations Special Fund (55 percent) and the Government of Ecuador (45 percent). The major project in the UN plan involves the build up of the Departamento Nacional de Geología of the Ministerio de Fomento. Although still in its preliminary form, the plan envisions study of seven priority areas: (1) the highly mineralized area of Portoviejo; (2) the coal deposits at Azogues; (3) glass sands near Ancón and silica at Zaruma; (4) placer gold in Esmeralda Province; (5) the copper district of La Plata-Macuchi; (6) iron deposits of the Cordillera de Colonche; and (7) industrial clays in the district of Cuenca. The UN program also sent two geologists to study geochemistry and geophysics in France. The Departamento Nacional de Geología is currently seeking a suitable candidate for training in photogeology.

The government of Ecuador is also looking forward to the education of future Ecuadorean geologists through the establishment of the School of Mining and Geology in the Faculty of Chemistry of the Universidad Central de Quito. Through a bilateral program with the Government of France two professors are being provided to the School. The United States AID Agency also established a project to assist the School of Mines when the time is appropriate, since it is still too early to forecast how the School of Mines would develop, though it appears to have adequate assistance. In the interim there appear to be sufficient fellowships offered by various organizations to educate geologists in universities in Chile, Mexico and the United States.

In general, the field of geology and mineral investigations in Ecuador seems to be well provided for through the combined efforts of the United Nations Special Fund and USAID working in collaboration with Ecuadorean agencies. On the important subject of geologic and geomorphologic mapping for support of soil survey operations and groundwater investigations, however, no programs are in the offing.

Geological maps which provide information regarding the age and class of rocks in various strata are particularly useful in understanding the parent material from which agricultural soils are derived. This is particularly important in volcanic and arid regions common in Ecuador. Geomorphological maps and studies concerned with relief and landforms and the factors which influenced their formation are helpful in understanding runoff, streamflow and groundwater accumulation as well as in the classification of soils. The need for this kind of mapping in combination with future soil and groundwater studies in Ecuador is clearly indicated.

Soils

1. Status of Soil Mapping

Soil information available in 1964 in Ecuador provides a fair general knowledge and description of the more important soils in accordance with standard soil classification terminology. Delineations of soils at a scale of about 1:2,000,000 had been made for the whole country, and at 1:1,000,000 for the province of Azuay. More detailed mapping is available only for small, scattered areas. Use and management studies exist for particular areas but are not related to a general evaluation of soil resources. The very few detailed or semidetailed maps found to be available are scattered among many agencies and are largely unknown to the public. The reconnaissance information provides a basis for more detailed study of the soil resources, but information at a scale useful for actual decision about development, use, and management of soils is exceedingly limited.

The following is an inventory of the maps and reports observed by the Mission:

Miller, E. V. "Agricultural Ecuador." IN: Geographical Review. 1959. Vol. 49 No. 2, pp. 183-207.

Frei, Erwin. Informe al Gobierno del Ecuador sobre Reconocimiento Edafológico Exploratorio. FAO. No. 585. 1957. 35 pp.

López Cordovez, L. A. Estudio Preliminar de las Zonas Agrícolas del Ecuador. Junta Nacional de Planificación y Coordinación Económica. 1961.

Küpper, Alfredo. Informe al Gobierno del Ecuador sobre el Programa Nacional de Suelos. FAO. No. 144. 1961.

Küpper, Alfredo, et.al. Unpublished reports on special areas and problems submitted to such agencies as the Junta Autónoma del Ferrocarril del Norte, Asociación Nacional de Bananeros, Instituto Nacional de Colonización, Comisión Nacional de Trigo, Centro de Reconversión Económica del Azuay, Cañar y Santiago Morona.

Andrade, V. H. Unpublished maps and descriptions for small soil survey areas in the inter-Andean valleys.

Pacheco, Rafael. Unpublished reconnaissance maps and descriptions for areas near Santo Domingo de los Colorados and on the eastern slopes of the Andes.

Thirron, Joseph. Unpublished detailed maps and descriptions for three haciendas in the Andes.

Peña Herrera, Julio. Estudio de los Suelos de las Zonas Trigueras del Ecuador y su Fertilidad. Universidad Central de Quito, IN: Anales. 1961. No. 90/345, pp. 221-238.

The Departamento de Suelos of the Ministerio de Fomento is currently carrying out two studies: the first, a semidetailed study of the Zona de Salinas, and the second, a general reconnaissance survey of the Provinces of Esmeralda, Manabí, El Oro and Carchi, and of the Región Oriental.

The Caja Nacional de Riego holds unpublished detailed soils and land capability maps for five small zones having a total area of about 30,000 hectares. In conclusion, the knowledge of soils is completely inadequate for the execution of Ecuador's proposed development activities, and very little effort is being made to remedy this deficiency.

2. Evaluation of Institutions

Soil use and management work, including research on soil fertility, erosion control, drainage, crop adaptation, etc., have been carried on by many agencies in Ecuador, including the Departamento de Suelos of the Ministerio de Fomento, the Caja Nacional de Riego, the Instituto de Tierras y Colonización, the Universidad Central de Ecuador, the commodity organizations such as the Comisión Nacional de Trigo, the Asociación Nacional de Bananeros, and probably others.

Soil workers are so scattered, however, that no one agency has a really effective program; mapping is being done by the Ministerio de Fomento, the Caja de Riego, and the Instituto de Tierras y Colonización. The latter probably has the most productive program, but no agency's program can be considered adequate to the needs.

Two soil chemistry laboratories are operating in Quito. One of them, in the Universidad Central de Ecuador, is used for normal course work, but also undertakes soil fertility testing as well as characterization analyses for soil surveys. While both of the laboratories are well-equipped and efficiently run, neither is equipped for mineralogical analyses. A third, less developed laboratory is located in Guayaquil.

Dr. Alfredo Küpper of FAO in his Informe al Gobierno del Ecuador sobre el Programa Nacional de Suelos (1961) recommends that all soil laboratories plus soil survey activites be gathered into a Servicio Nacional de Suelos, presumably within the Instituto Nacional de Investigaciones Agropecuarias. Whatever its location, the important point is that Ecuador desperately needs to consolidate under one roof its different capabilities in the field of soils in order to build an effective program geared to development needs. The number of soil scientists in the country must also be greatly augmented.

3. Facilities for Training in the Soil Science Field

Four universities in Ecuador have agronomy faculties: the Universidad Central de Ecuador (Quito), and universities in Guayaquil, Portoviejo, and Loja. Specialization in soils is available in all four, but the Universidad Central de Ecuador is graduating the majority of the soils specialists. In that university five years of perscribed course work, including three semesters of soils courses, is required of all students for the agricultural engineering degree. A thesis, requiring another six months of work, is also required and provides opportunity for specialization in some aspect of agronomy, including soils. From 20 to 30 students graduate in agronomy each year, but only one or two specialize in soils.

The training received is generally equivalent to that of undergraduate programs in agricultural colleges in the United States. Several agricultural engineers have successfully gone into graduate work in universities in the United States and have received Master of Science degrees.

Present facilities probably could produce two or three times the present number of soils technicians but special advisers for thesis programs are needed. There is no post-graduate program, and graduate training at the Master of Science level will be needed for perhaps five to 20 persons over the next 10 years, and several Ph.D. graduates could be used to advantage. Rather than institute a post graduate program, however, it would be advisable, perhaps, to continue sending students to other countries to complete their graduate work. Every effort should still be made, however, to strengthen the undergraduate programs, to prepare more and better qualified students for graduate work in such countries as Costa Rica and the United States as well as in Europe. The need for soils scientists in Ecuador is critical.

Meteorology [6]

The oldest continuous climatic records in Ecuador are those for Quito, which date back to 1891. In 1922, a national meteorological service was organized and the network of stations was gradually expanded to include a synoptic network of about 19 stations covering the more densely populated coastal and sierra regions. The total climatological network now includes about 37 stations, with only one located in the vast tropical Amazon region, and two in the Galapagos Islands. The average length of record of data collected at the station, is only about eight years and some of the stations have discontinuous records. Only 86 rain gauges are reported. On the whole, the average density of stations is less than one per 3000 Km^2. The meteorologic service (Servicio Meteorológico) has summarized climatic data by months, but the last published meteorologic bulletin only includes data as current as 1958.

In 1959 the World Meteorological Organization (WMO) and the UN Special Fund sent a mission to Ecuador which resulted in an agreement with the Government of Ecuador to establish a program to augment meteorologic and hydrologic data collection. Plans for the program were worked out jointly by the original Servicio Meteorológico, the Junta Nacional de Planificación, the Caja Nacional de Riego, the Instituto de Electricidad, the Dirección de Recursos Hidráulicos

6. In the course of the evaluation of existing meteorologic data and institutions the mission has drawn heavily upon the work of Dr. Peter Duisberg who was in Ecuador in May of 1962 as a member of a team of technicians of the Inter-American Committee for Agricultural Development (ICAD) engaged in an inventory of basic data pertaining to agriculture in Latin America.

y Electrificación, and the WMO mission. It provides for the improvement of the synoptic network of meteorologic stations, the establishment of an agro-meteorologic network and the development of a hydrometeorologic network adequate for studying energy resources, potable water, irrigation and navigation.

Specifically, it is a four-year program designed to increase the meteorologic station network from the original 37 second order stations to 3 first order stations, 45 second order stations, 61 third order stations, and 145 pluviometric stations (total 254 stations).

The first order stations are to include determinations of soil moisture and humidity, and temperature of bare soil and soil covered with mulch and with grass, and the quantity of dewfall. Major observations are planned nine times daily in the three first order stations, four times daily in the eight additional second order stations, and once daily in the 61 third order stations. Full-time trained observers would perform these observations. Radio sondes will be made from one station and solar radiation measurements from eleven. A substantial amount of new equipment is included in the program, as well as provisions for training personnel. The UN Special Fund has donated a total of $405,000 to the project.

In 1961, the Servicio Meteorológico was reorganized by presidential decree, as the Servicio Nacional de Meteorología e Hidrología (SNMH) with a greatly expanded budget. The Air Force continues to operate five stations and PANAGRA one, but all data is being sent to the SNMH. SNMH's reorganization has been well conceived and the UN Special Fund program is well underway. The new network will be very useful in supplying information for many resource development programs, even though the period of record will be very limited in many cases. The staff of the Servicio is being expanded and trained, full time observers are being installed at the most important stations, and with the aid of the UN grant the instrumentation is being standardized and improved. The network will not be as extensive as might be desired, especially with regard to climatic data needed for agricultural development programs. Also, additional stations in the undeveloped eastern region and on various small watersheds would be especially useful for future development. The program constitutes a major step forward, however, and with continued efficient administration can undoubtedly be supported by utilization of financial resources of the nation.

After the basic data collecting network is functioning well, attention should be given to the analysis of the data, climatological studies and the preparation of climatic maps.

Hydrology 7/

1. Groundwater

Very little is known about Ecuador's groundwater resources, and such information as is available is of very recent origin. The Dirección General de Recursos Hidráulicos y Electrificación has collected limited information on

7. Ibid.

such areas as the valleys of Torqui and Cumbe of the Cantón Cuenca in the province of Azuay, where irrigation with groundwater has been developed on a moderate scale.

In 1963, the United Nations Special Fund initiated a project in the Province of Manabí for the survey of domestic and industrial water supplies for several towns. In addition to studies of surface water supplies, the project includes groundwater investigations in an area bounded by the towns of Jipijapa, Montecristi, Rocafuerte, Junín and Santa Ana. Approximately 50 wells will be drilled during the course of completion of the Special Fund Program.

In general Ecuador's groundwater reserves are highly underdeveloped, although the potentials for development, particularly in the coastal region, are considered to be so great that collection of basic data is indispensable.

2. Streamflow

Very little information has been collected to date on the characteristics of the streams of Ecuador. Some streamflow and sediment data has been collected by the Dirección General de Recursos Hidráulicos y Electrificación, the electric company of Guayaquil (EMELEC) and the Caja Nacional de Riego. By 1962, however, Ecuador possessed only 18 flow meters with an average period of record of 2.3 years. The situation is summarized in unpublished 1959 studies on "The Water Resources in Ecuador, Present State of Hydrometeorology" by R. Schroeder, and "Report on Water Resources in Ecuador" by C. Hawes for ECLA/FAO/WMO.

The new Servicio Nacional de Meteorología e Hidrología, described in the previous section, plans to establish 110 hydrometeorological stations throughout the country with the assistance of the UN Special Fund. In general, the program of the SNMH has been well formulated and if developed according to plan may remedy some of the most important deficiencies in streamflow data which retard development planning. The shortness of the period of record of the streamflow gauges however presents serious difficulties to the immediate planning of water resource development programs.

The Dirección General de Recursos Hidráulicos y Electrificación had made preliminary studies on Chimborazo Volcano to explore the possibility of utilizing glacier meltwater for irrigation. Data have been collected on the flow of several springs to determine use of this groundwater source for irrigation.

Vegetation, Ecology and Forestry

Knowledge of Ecuador's vegetation is very general, and limited to taxonomic descriptions with little work done in such fields as plant geography and plant sociology. An important ecologic survey with useful implications for agricultural development is the Mapa Ecológico de la Costa y Sierra del Ecuador (Preliminar) completed in 1963. The final map will probably be published at a scale of 1:1,000,000. This work, based on the ecologic classification system of L. R. Holdridge, is a significant step forward and supersedes in importance the limited number of vegetation maps previously produced. The most useful of these latter is a very general vegetation map prepared by FAO in 1959, in its Bulletin 748, Informe al Gobierno del Ecuador sobre un Estudio Forestal, at a scale of about 1:5,000,000. Worthy of note also is the work of Misael Acosta Solís in his publication, Fitogeografía y Vegetación de la Provincia de Pichincha, 1962, Pan American Institute of Geography and History (PAIGH) publication 249.

No agencies or institutions, and only a few scientists are dedicated to the field of plant science in Ecuador, and the facilities for training students in this field is very limited. With respect to agricultural and forest development, trained botanists and forest ecologists skilled in photo interpretation would be valuable in conducting resource surveys.

Ecuador is just beginning to develop useful basic forest resources data. One of the first and most useful reference works is The Forests of Western and Central Ecuador, U.S. Forest Service, U.S. Department of Agriculture, June 1947. Other more recent documents include the Informe al Gobierno del Ecuador sobre un Estudio Forestal, FAO Report No. 728, and Desarrollo de las Industrias Forestales en las Regiones de Guayaquil y San Lorenzo, FAO Report No. 1125. These documents are useful references but contain no important mapping. A five-year program was begun in 1963, however, under the sponsorship of the UN Special Fund and the Food and Agriculture Organization of the United Nations (FAO), designed to survey the forest resources of northwestern Ecuador--specifically the area east of the Ríos Esmeralda and Blanco--in order to promote development of the timber industry. This study area covers approximately one million hectares containing primarily evergreen broadleaf forests, and consists of forest inventory and mapping, establishment of a pilot sawmill and a tannin extract plant, and the purchase of logging equipment to demonstrate modern logging techniques. The United Nations Special Fund has provided $825,000 for the study. The forest inventory phase of this project will provide and excellent opportunity for Ecuadorean plant scientists to work in close cooperation with foreign experts. While there is no question as to the value of the UN Special Fund-FAO forestry project in developing data about the timber resources of the most important forest areas in the country, it must be noted that very significant forest areas remain, the data from which will be essential to Ecuador's development.

Land Use and Land Capability

Land use mapping, although in its infancy in Ecuador, has been given a surprising amount of attention by the country's technicians. A general land use map at a scale of 1:1,000,000 was prepared in 1961 for the Junta Nacional de Planificación y Coordinación Económica by L. López. For gaining a general impression of major agricultural zones of Ecuador, this map and the accompanying report, Estudio Preliminar de Zonas Agrícolas del Ecuador, are the best references currently available. A map of the banana zones was also prepared by C. Herrera in 1960, at a scale of about 1:3,000,000. The Dirección de Bosques of the Ministerio de Fomento, in collaboration with the Junta Nacional de Planificación y Coordinación Económica, in 1963 prepared a map entitled "Mapa del Uso Actual de las Tierras en la Costa y Sierra del Ecuador," which is basically derived from the ecologic map of the same area with some additional aerial observations. To date, it has not appeared in published form.

The only land use mapping produced at larger scales and based on photographic interpretation is entitled "Utilización del Suelo en la Hoya del Guaillabamba," and was prepared by the Instituto Panamericano de Geografía e Historia as part of its Plan Piloto del Ecuador, 1961. A map at a scale of 1:100,000 shows the valley areas near Quito.

Land use mapping at large scales of major agricultural areas should be a part of any future plan of an integrated study of natural resources in Ecuador. Fortunately, there is a recognition in the country of the importance of this kind of map data.

Land capability mapping, 8/ on the other hand, has until now received very little attention in Ecuador. The only land capability map available in Ecuador is that completed by the Caja de Riego Nacional for five of its irrigation projects. The need for further mapping is critical in support of many different types of agricultural development projects, including colonization and agrarian reform. Land capability mapping is probably one of the most critical basic data needs in Ecuador and very little is being done to remedy the deficiency.

Summary

Aerial photography

Aerial photography in Ecuador, which is so basic to all forms of mapping and natural resource investigations, is only partially satisfactory. Small scale aerial photography being taken by the U.S. Air Force in cooperation with the IGM is filling basic needs for mapping photography. It is unfortunate that this important program can not be accelerated and that in all probability some areas will remain without coverage. Climatic conditions present serious difficulties for flying in Ecuador, thus making it desirable that aircraft be stationed in the country on a long term basis. Photographic coverage of important areas in the coastal region of the country is critically needed and every effort should be made to obtain it, so as to avoid slowing down the national topographic mapping program.

Larger scale aerial photography of important development regions is being given attention, but the urgency is such that delays experienced in getting the program underway constitute a serious problem.

8. Land capability mapping as it is presently carried out in most of the Western Hemisphere is basically an empirical classification of soils productivity, and as such is considered a part of the field of soil science.

Topographic mapping

While very little high quality topographic mapping has been completed in Ecuador, efforts are being made to remedy this serious deficiency and at the same time build up the capabilities of the Instituto Geográfico Militar, which is Ecuador's responsible mapping agency. The IGM-IAGS project for national topographic mapping supported by the $1.8 million Development Loan Fund loan is an important and forward-looking program. It should provide over the long-term a highly accurate product which will serve many purposes.

While the IGM has estimated that the bulk of the program will be completed in only five years, the mission feels that seven to 10 years is a more realistic estimate if the experience of other countries is any guide. Consequently, it is evident that programs such as natural resource investigations or cadastral surveys, which require some sort of a map base, should not await the availability of topographic maps. Semi-controlled mosaics, controlled mosaics or planimetric maps should be produced for such purposes where needed.

Geology

Until recently, the subject of geology and mineral investigation was paid little attention in Ecuador. As of mid-1964, very little geologic mapping had been carried out and institutional and educational facilities do not exist which could supply technicians for a national program for geologic and mineral studies. In recognition of this fact and in light of the potential for discovery of mineral deposits in the country, the UN Special Fund, in cooperation with the Government of Ecuador, is in the process of initiating a national program of geologic and mineral investigations. The UN Special Fund is also providing assistance in training through fellowships and exchange of professors with European institutions, and USAID is assisting in the development of geologic institutions and training facilities. Together, the UN Special Fund and the USAID programs appear to cover the most critical needs for geologic and mineral investigations in Ecuador and the development of local institutions and training facilities.

The areas which have been overlooked are geomorphologic and geologic investigations in support of soil survey operations, and groundwater studies. The field of engineering geology is also retarded. It would be highly desirable to have an engineering geology branch established either within the Ministerio de Obras Públicas or the Ministerio de Fomento.

Soils

Knowledge of soils in Ecuador is so limited as to constitute a major obstacle to the intelligent planning of agricultural development and the execution of specific projects. The only maps available are highly generalized and at small scales which serve only for general orientation, and detailed maps of a few areas where irrigation or other projects are underway. The latter maps cover only a fraction of the area where such information is needed.

Numerous institutions are carrying out soil surveys with the result that soils scientists are scattered and no single agency has a really effective soils survey program. The number of soils scientists is judged inadequate to the country's needs and only limited undergraduate level training is available. Efforts need to be made to increase the number of persons receiving undergraduate training in soils in Ecuador and soils technicians should be sponsored for graduate training in other countries.

The magnitude of the task of acquiring information about the soils of Ecuador is so great, and the institutional and educational facilities so meager, that future investigations should be concentrated, at least initially, in limited areas where the data are needed urgently for development. At the same time it is important that the government make efforts to consolidate its scattered technicians in the field of soils into a single organization so as to build a reasonably effective mapping program. Even if this is accomplished, considerable technical assistance will still be needed from abroad, in addition to expanded training efforts locally.

Meteorology

In meteorology as in geology, the availability of information has been found to be seriously limited, but through the efforts of the United Nations and the Government of Ecuador a program is underway to remedy this serious deficiency and build up the institutional capabilities of the country. The UN Special Fund has pledged $404,000, under a four-year program being executed by the World Meteorologic Organization in cooperation with Ecuadorean agencies. The program is designed to greatly augment the network of meteorologic stations in the country and to provide training of technicians and development of the newly created National Meteorologic and Hydrologic Service. The network of stations will not be as extensive as might be desired but the program will be a major step forward for the country. A difficulty to be faced in the next few years is the fact that the period of record of the newly created stations will be relatively short. Until several years have passed, technicians will have to rely on extensive interpolations of data, with all of the inherent risks.

Hydrology

Major efforts in promoting the systematic collection of hydrologic data have ocurred only in recent years. The UN Special Fund program mentioned previously is also providing for the establishment of 110 hydrometeorological stations throughout the country which should eventually remedy some of the most serious deficiencies in streamflow data for use in planning water resource development. For the immediate future, however, the short period of record available at the new gauging stations will present serious difficulties in planning irrigation projects, hydroelectric development, etc. This is particularly serious for the coastal region of the country where considerable potential for water resource development exists and some irrigation projects are already underway. For the short run, supplementary methods for estimating streamflow will have to be employed, including aerial photographic interpretation, short-term streamflow gauging of small tributaries, etc.

Knowledge of groundwater potential in Ecuador has been found to be extremely limited, despite the fact that there are great needs for development of this resource in the coastal region and clear indications that potential exists. The UN Special Fund project in the province of Manabí for developing industrial and domestic water supplies includes groundwater investigations, but this project is highly localized. The need persists for a comprehensive program of groundwater studies, particularly in the rapidly developing parts of the coastal region.

Vegetation, Ecology and Forestry

In Ecuador, as in most of Latin America, investigations of vegetation and ecology are just being initiated. An ecologic map of the coast and sierra region of the country has recently been completed. This is, of course, only a first step; future investigations of soils and land capability should include further mapping and more detailed investigations of vegetation.

Forestry data are also fairly rudimentary. No detailed mapping or data pertaining to forest resources have been encountered and the government agencies in this field are just beginning to develop. There are virtually no facilities in the country for training professional foresters.

As in the fields of geology, hydrology and meteorology, however, the United Nations Special Fund has embarked on a program to assist the Government of Ecuador in building up its capabilities and in carrying out needed investigations. A five-year UN Special Fund forestry project, which began in late 1963, includes a forest inventory and the mapping of roughly one million acres of forests in northwestern Ecuador, and the establishment of a pilot sawmill, a tannin extract plant and demonstration of modern logging techniques. This well-conceived project will undoubtedly result in the development of Ecuador's most important forest area, and in considerable training and build-up of local institutions. Other forested areas require investigation to stimulate development, particularly in connection with colonization projects.

Land Use and Land Capability

Mapping of present land use has received some attention in Ecuador and several small scale maps are available which cover all or a major part of the country. Some medium scale (1:100,000) mapping of the province of Pichincha has been accomplished with the use of aerial photographic interpretation. Large scale (1:20,000) mapping of major development areas, however, has not been undertaken although such information is greatly needed.

Land use capability mapping, which is basically the composite analysis of environmental factors influencing agricultural and other land use, can be viewed as an end product of many of the fields that have been described previously. Very little work of this type has been carried out in Ecuador, although the importance of such data cannot be overemphasized. In addition to providing a necessary basis of information for planning agricultural development in relation to productive capacity, land capability studies have important application in the determination of land value for purposes of land taxation and agrarian reform. There is probably no other form of data pertaining to natural resources which Ecuador needs more urgently.

Conclusions and Recommendations

On the basis of the inventory of existing natural resources data and mapping in Ecuador, and on the evaluation of institutions and training facilities, several major conclusions have been arrived at:

1. Despite a number of excellent programs currently underway in the fields of geology, forestry, meteorology and topographic mapping, the amount of existing mapping and basic data pertaining to natural resources in Ecuador is very limited and completely inadequate to the needs of national economic planning and the preparation of specific development projects.

2. The number of technicians within the country able to carry forward investigations of natural resources is inadequate to the needs of the country, indicating that a considerable amount of technical assistance from the outside will be necessary in order to initiate any major integrated program of natural resource investigations.

3. Training facilities within the country for preparing resource technicians are limited but could be supplemented by fellowship programs abroad and on-the-job training locally during the execution of projects.

4. The magnitude of work remaining to be done in resource investigations in the country is so large that a comprehensive national program of such investigations would be too expensive for the country to support at this time. Furthermore, the amount of data that would evolve from such a national project, if carried out, could not possibly be absorbed and utilized effectively by existing technicians and institutions.

On the basis of these conclusions it is recommended that natural resources surveys in Ecuador should be concentrated in a limited area possessing considerable potential for economic development, where the data would be of most immediate use in planning and project preparation. By undertaking a program of limited scope it is felt that more effective use can be made of available Ecuadorian technicians, substantial training can be provided, and at the completion of the program an adequate cadre of Ecuadorian specialists would be available to provide continuity and assure effective utilization of the data produced in the project.

Selection of the Guayas Basin Region

In order to define an appropriate area, studies were made of existing data pertaining to the natural resources of Ecuador and an extensive number of interviews was held with Ecuadorian agencies and industrial experts in many fields.[9]

9. For a complete list of interviews see "Preliminary Report of the OAS Mission for Preparation of the Terms of Reference for a Plan of Natural Resources Inventory in Ecuador." Organization of American States, Doc. UP/G.7/2.

Opinions were solicited from the Instituto de Electrificación on the matter of hydroelectric potentials, from the Ministerio de Fomento on matters of forest and soil potentials, from the Instituto de Colonización for areas with priority for colonization, and from the Junta Nacional de Planificación on the over-all strategy of regional development within the context of national development. The general consensus derived from these interviews was that the coastal region of the country holds the largest immediate promise for development, a judgement which is further corroborated by available economic and resource data. Within the coastal area, the Guayas River Basin appears to be the focus of present development and includes areas containing large unexploited resource potentials. In general, high quality resources and large existing investments in infrastructure make this area a natural site for intensified development efforts. The Guayas River Basin has the further advantage that as a natural physical unit it is ideally suited to regional development on an integrated basis.

It was therefore agreed, during the course of the OAS technical assistance mission in July 1962, that efforts should be focused on developing plans for integrated investigations of natural resources within the Guayas River Basin. In attempting to do so, however, certain difficulties were encountered. The possibility of carrying out a comprehensive and detailed resource inventory of the entire Basin was ruled out because of the high cost of such a program and the waste involved in making detailed studies of large portions of the Basin with apparent limited development potential. At the same time, the amount of existing information about natural resources within the Guayas Basin was so scanty as to preclude the possibility of accurately delineating zones with sufficient potential to justify the cost of feasibility surveys of natural resources. Therefore, in the "Preliminary Report of the OAS Mission for Preparation of the Terms of Reference for a Plan of Natural Resources Inventory in Ecuador," general methods and procedures for resource investigations were outlined and the costs and specifications for needed aerial photography were indicated, but no attempt was made to prepare a detailed program for natural resource investigations.

Further field investigation was judged necessary to establish a sound basis for such recommendations, and at the request of the Junta Nacional de Planificación, a second OAS technical assistance mission to the Government of Ecuador was undertaken with the purpose of providing a more complete informational base for resource development in the Guayas Basin.

The Guayas River Basin

CHAPTER II

The Natural Resources of the Guayas Basin

Location

The Guayas Basin of Ecuador is located in the coastal region of the country, between 0°15' and 2°25' south latitude, and 78°40' and 80°30' West longitude. It is bounded on the east by the axis of the Andean Cordillera and on the north by a westward extending spur of the Andean Cordillera which separates the southward draining Guayas watershed from the northward draining Esmeraldas watershed. The western boundary is made up of a series of low mountains which include, from north to south, the Cordillera de San Pablo de Balzar, the Cerros de Puco and the Cordilleras of Colonche and Chongón. The southern boundary is less well defined because of the flatness of the lands around the mouth of the Guayas River. For the purpose of this report it has been defined as the divide between the Río Taura-Corozo and the Río Churute (see Fig. 1).

The principal tributaries feeding the Guayas River are the Daule (260 kilometers long) and the Babahoyo-Zapotal (175 kilometers long). The north-south dimension of the basin is 225 kilometers, while the east-west dimension varies from 190 to 240 kilometers. The total area of the watershed is approximately 33,640 Km^2, making it the largest drainage network flowing into the Pacific Ocean from the South American continent. Eight provinces of Ecuador are located entirely or partly within the basin.

Climate

The Guayas Basin probably has as great a diversity of climate conditions as any area of comparable size in the Western Hemisphere. This extreme diversity is due largely to the influence of the Andean Cordillera and ocean currents which flow along the coast of Ecuador. Local climatic variations and those of a cyclical nature have been analyzed, though they cannot be plotted with a great degree of certainty owing to the lack of adequate long term records. Nevertheless, the precipitation maps which have been prepared by the mission (Figures 2, 3, and 4, and Appendix A) can help to provide a basis for understanding soil, vegetation and land use patterns in the Guayas Basin and also point to some of the major problems related to agriculture and the need for irrigation in selected areas.

Temperature

Because of the Humboldt Current's cooling effect during most of the year (May to December), the Guayas Basin is characterized by a somewhat atypical temperature regime, differing from similar latitudes in the tropics. The Humboldt Current cools the southwest winds that penetrate the Basin, which in addition to lowering the average temperatures cause cloudy conditions as far inland as Babahoyo. Consequently, there is only one maximum temperature peak over most of the lowland plain, occuring from March to May. Throughout the Basin the difference between the annual mean minima and maxima temperatures is slight, around 2.0°C. At Santo Domingo de los Colorados the mean maxima and minima are 22.9°C. and 21.1°C. respectively; at Babahoyo they are 26.7°C. and 23.4°C. Throughout the Guayas Plain, higher temperatures occur during the months of maximum rainfall while lower temperatures occur during the drier months.

Temperatures decrease with elevation, with high altitude cold permitting perennial snowfields on the highest peaks, while areas near sea level are typically tropical.

Precipitation

There is a general tendency toward decreased precipitation from north to south in Ecuador, as is illustrated on the map showing the average annual rainfall (Fig. 2), but this is quite overshadowed by the east-west variations due to topography.

Along the western slopes of the Andes, precipitation does not attain the elevated figures of the eastern Andean front, although total annual rainfall above 3,000 mm. has been recorded in the Santo Domingo de los Colorados and Bucay zones. Vegetation indexes indicate that similar heavy precipitation prevails all along the lower elevations of the western Andean front. The coastal lowlands of Ecuador are characterized by a single wet and a single dry season, differing from the rainfall pattern of the eastern Cordillera flanks where two peaks of maximum precipitation are registered.

In the Guayas Basin, maximum precipitation occurs at the onset of the rainy season, beginning in January and normally reaching its peak in March (see Fig. 3). The atypical rainfall pattern seems to be due to the influence of ocean currents, particularly the El Niño current whose warm waters, originating in the Gulf of Panama, cross the Equator and move along the Ecuadorian coast in the months of December through March. During these months moisture-laden air masses over the current move inland to discharge their humidity as convectional or orographic precipitation in the Basin and along the Andean front. During the dry months the El Niño current retreats to the north side of the Equator, and the cold Humboldt Current flows north to bring about arid atmospheric conditions similar to those prevailing along the Peruvian coast. Rainfall diminishes after May, although effectively dry conditions do not occur until August and continue through November and December which are the transition months (see Appendix B). October has been selected as being typical of the dry season and is shown in Figure 4.

On the basis of precipitation, different rainfall regions in the Guayas Basin correspond geographically to north-south trending strips, the pluviometric characteristics of which vary not only with respect to total rainfall amounts, but also with regard to the length of the rainy season and its intensity. Proceeding from west to east the following conditions are encountered: between the 500 mm. and 1,000 mm. isohyets, in the western part of the Guayas Basin (see Figure 2) the rainy season lasts three months (January-March) during which time the monthly means surpass 100 mm. The dry season includes six months in which monthly rainfall averages less than 5 mm.

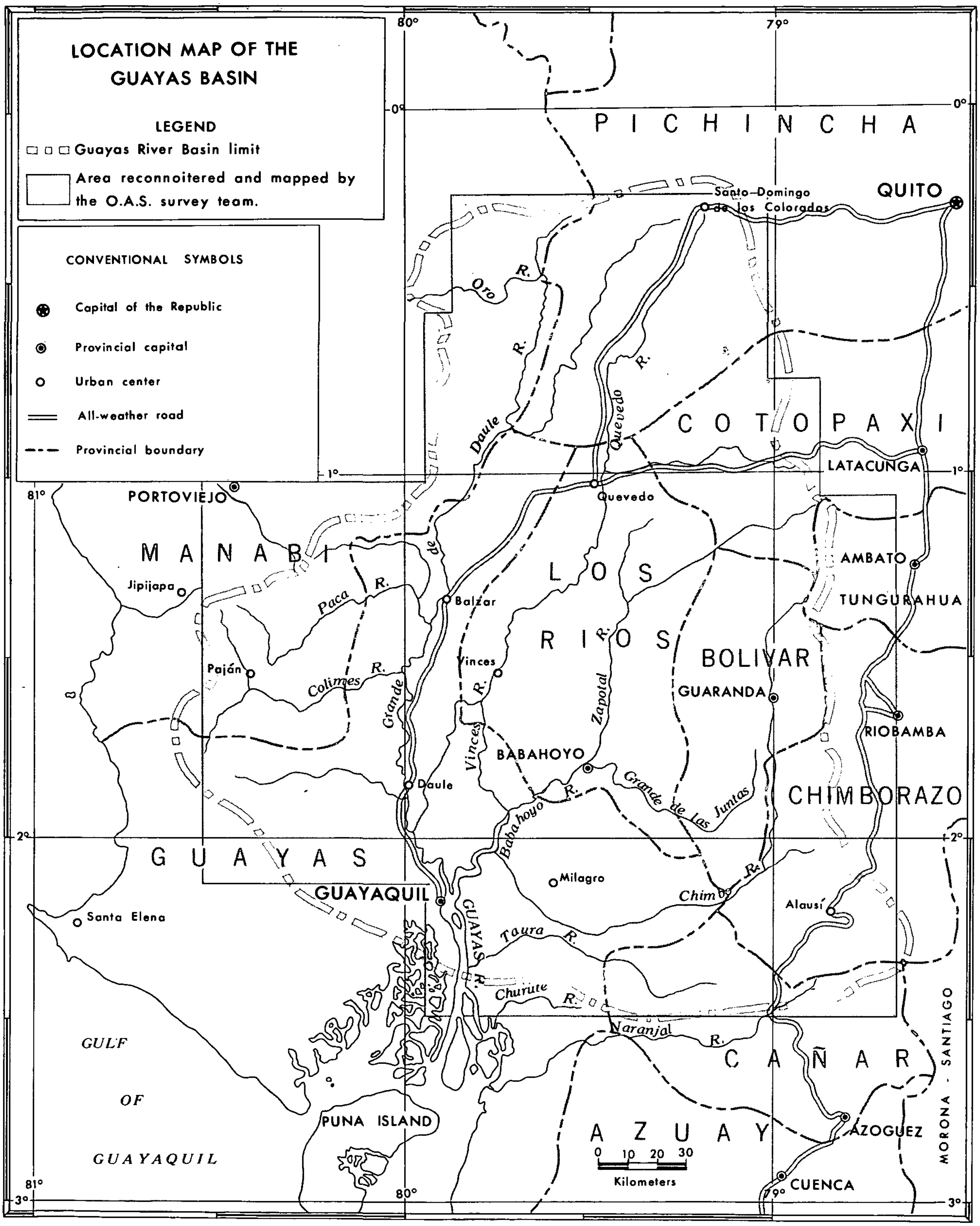
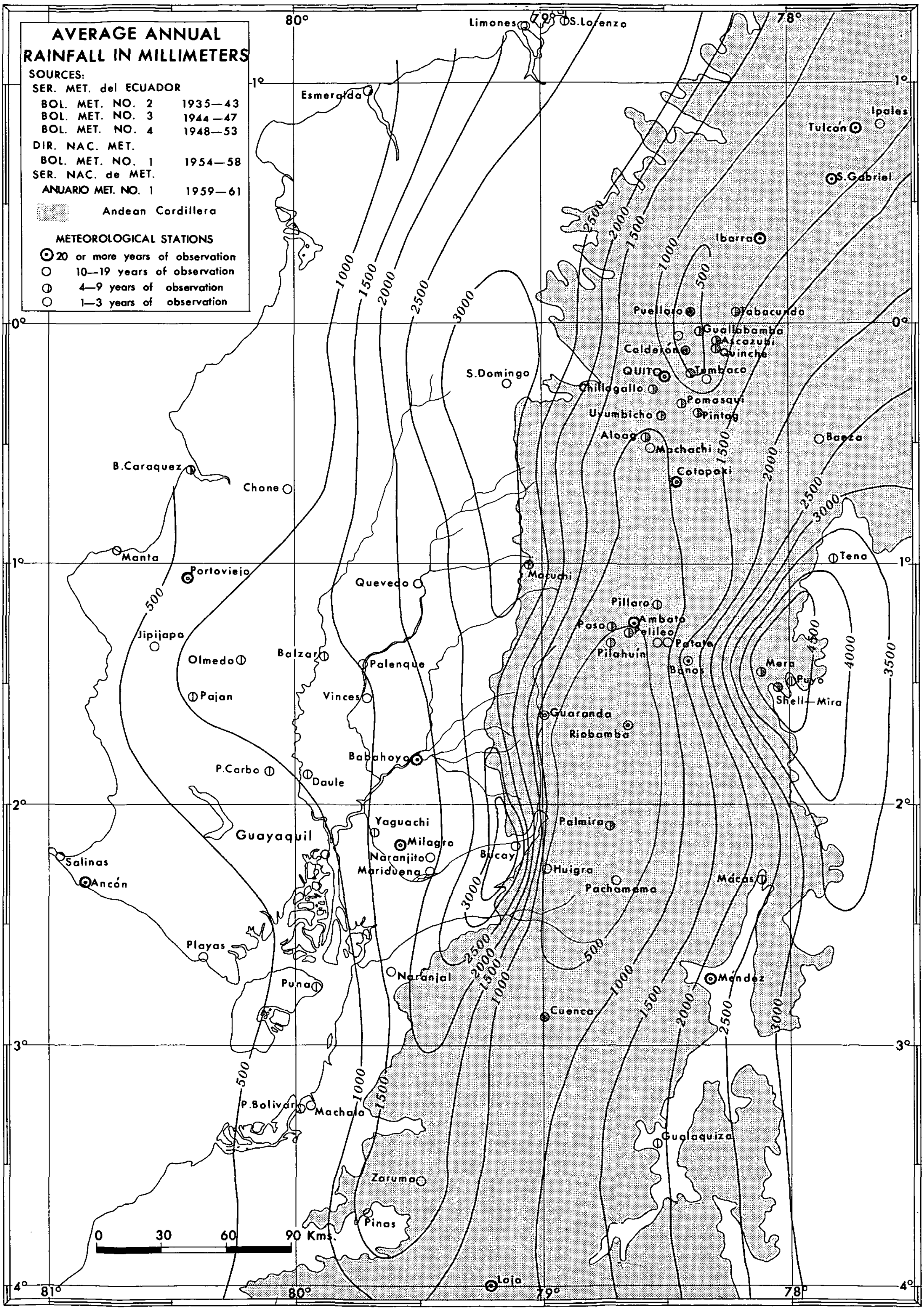

LOCATION MAP OF THE GUAYAS BASIN
LEGEND
Guayas River Basin limit
Area reconnoitered and mapped by the O.A.S. survey team.
CONVENTIONAL SYMBOLS
Capital of the Republic
Provincial capital
Urban center
All-weather road
Provincial boundary
PICHINCHA
QUITO
Santo Domingo de los Colorados
COTOPAXI
LATACUNGA
MANABI
PORTOVIEJO
Jipijapa
Pajan
LOS RIOS
Quevedo
Balzar
Vinces
BABAHOYO
BOLIVAR
GUARANDA
AMBATO
TUNGURAHUA
RIOBAMBA
CHIMBORAZO
GUAYAS
Daule
GUAYAQUIL
Milagro
Santa Elena
Alausí
CAÑAR
AZOGUEZ
AZUAY
CUENCA
MORONA - SANTIAGO
GULF OF GUAYAQUIL
PUNA ISLAND
Kilometers
0 10 20 30
80°
79°
81°
0°
1°
2°
3°

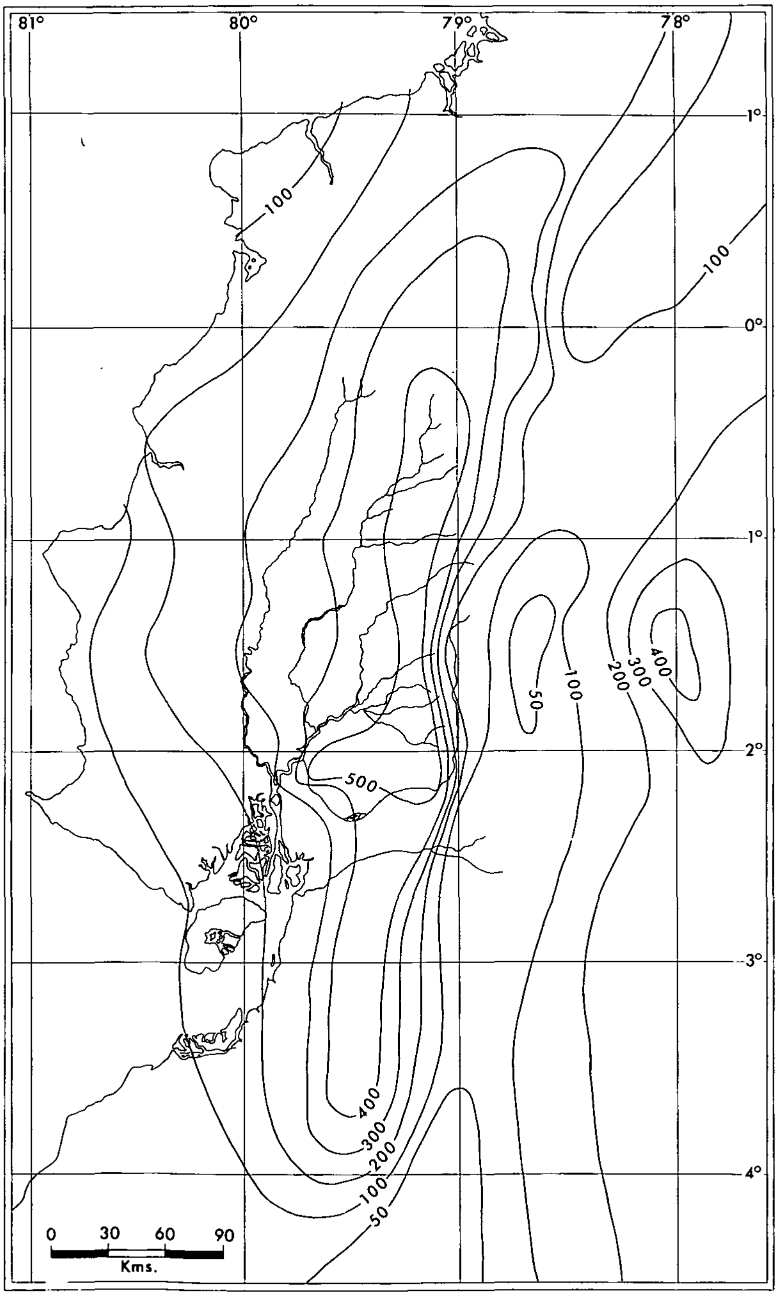
Fig. 1


AVERAGE ANNUAL
RAINFALL IN MILLIMETERS
SOURCES:
SER. MET. del ECUADOR
BOL. MET. NO. 2 1935—43
BOL. MET. NO. 3 1944—47
BOL. MET. NO. 4 1948—53
DIR. NAC. MET.
BOL. MET. NO. 1 1954—58
SER. NAC. de MET.
ANUARIO MET. NO. 1 1959—61
Andean Cordillera
METEOROLOGICAL STATIONS
20 or more years of observation
10—19 years of observation
4—9 years of observation
1—3 years of observation
Limones
S.Lorenzo
Esmeralda
Tulcan
Ipales
S.Gabriel
Ibarra
Puellaro
Tabacundo
Guallabamba
Ascazubi
Calderon
Quinche
QUITO
Tumbaco
S.Domingo
Chillogallo
Pomasqui
Uyumbicho
Pintag
Aloag
Machachi
Baeza
B.Caraquez
Chone
Cotopaxi
Manta
Portoviejo
Tena
Quevedo
Macuchi
Pillaro
Jipijapa
Paso
Ambato
Pelileo
Patate
Olmedo
Balzar
Pilahuin
Palenque
Banos
Mera
Puyo
Shell—Mira
Pajan
Vinces
Guaranda
Riobamba
Babahoyo
P.Carbo
Daule
Palmira
Guayaquil
Yaguachi
Milagro
Naranjito
Salinas
Bucay
Mariduena
Ancón
Huigra
Pachamama
Macas
Playas
Naranjal
Mendez
Puna
Cuenca
P.Bolivar
Machala
Gualaquiza
Zaruma
Pinas
Loja
0 30 60 90 Kms.
80°
79°
78°
81°
1°
0°
2°
3°
4°
500
1000
1500
2000
2500
3000
3500
4000
4500
Fig. 2.

MARZO
(MARCH)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

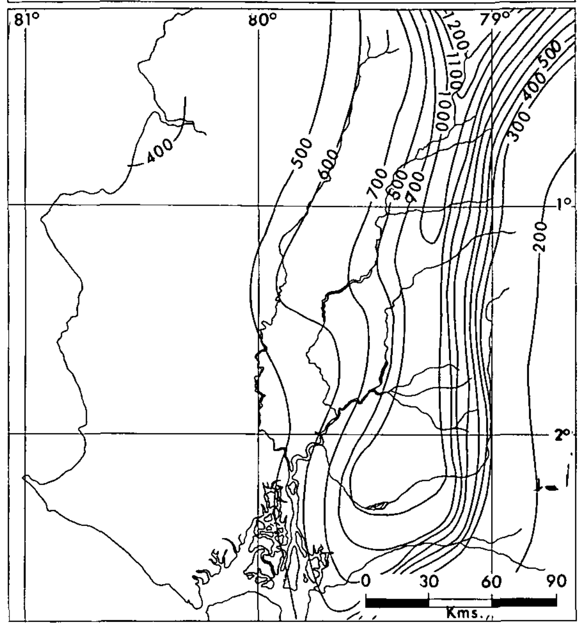
(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



MARZO
(MARCH)

MAXIMO ABSOLUTO MENSUAL DE PRECIPITACION EN MM.

(ABSOLUTE MAXIMUM MONTHLY RAINFALL IN MILLIMETERS)



MARZO
(MARCH)

MINIMO ABSOLUTO MENSUAL DE PRECIPITACION EN MM.

(ABSOLUTE MINIMUM MONTHLY RAINFALL IN MILLIMETERS)

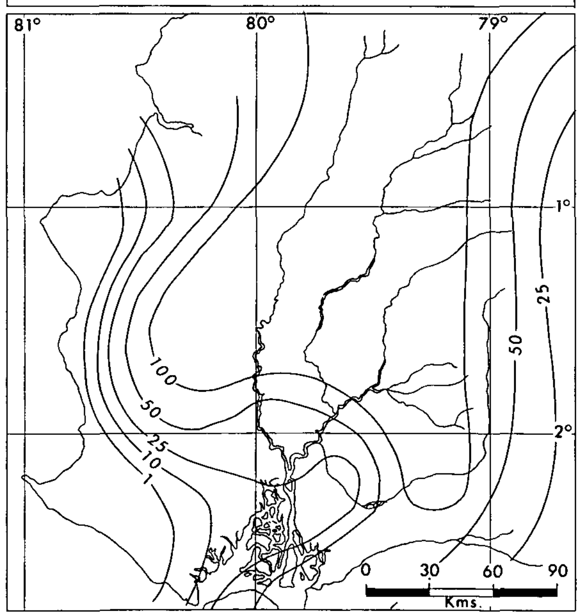
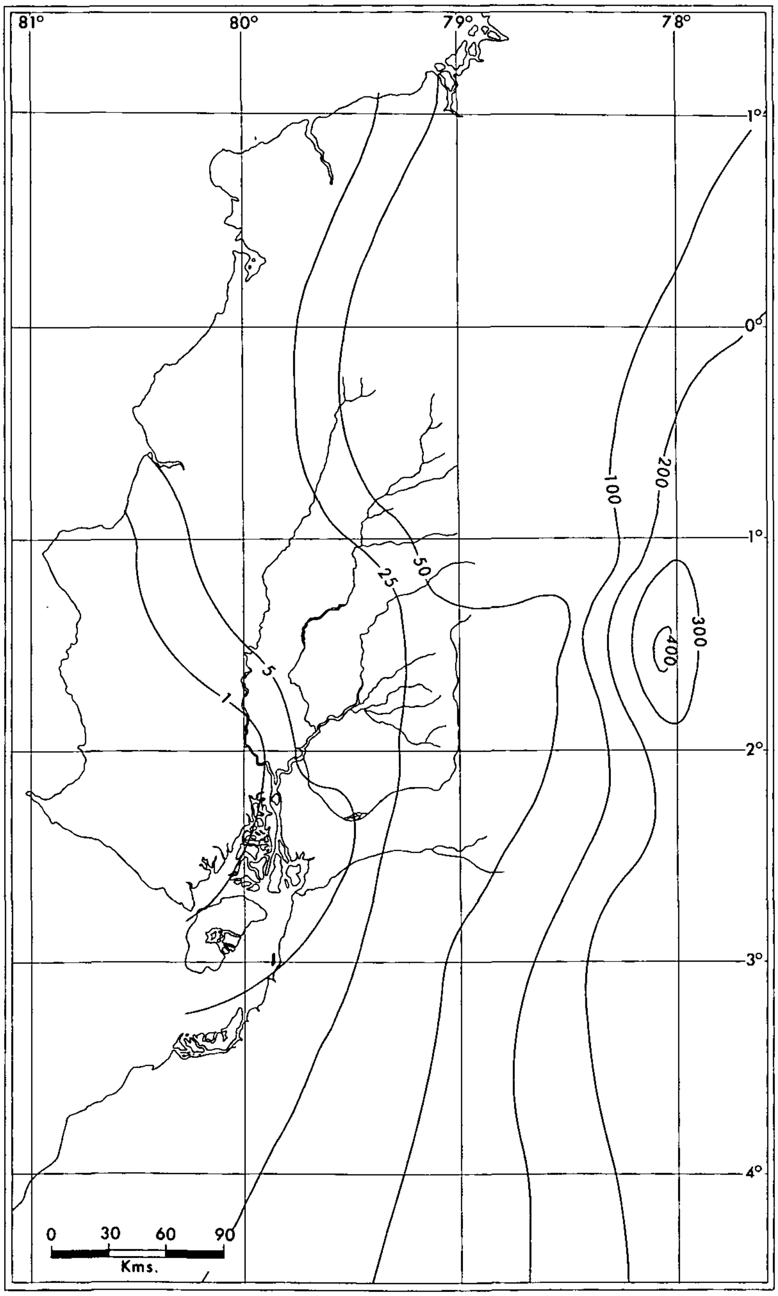


Fig. 3

OCTUBRE
(OCTOBER)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

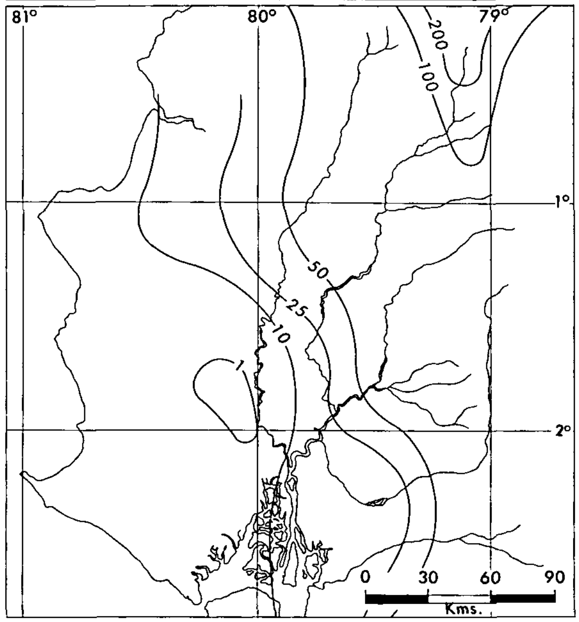
(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



OCTUBRE
(OCTOBER)

MAXIMO ABSOLUTO MENSUAL DE PRECIPITACION EN MM

(ABSOLUTE MAXIMUM MONTHLY RAINFALL IN MILLIMETERS)



OCTUBRE
(OCTOBER)

MINIMO ABSOLUTO MENSUAL DE PRECIPITACION EN MM

(ABSOLUTE MINIMUM MONTHLY RAINFALL IN MILLIMETERS)

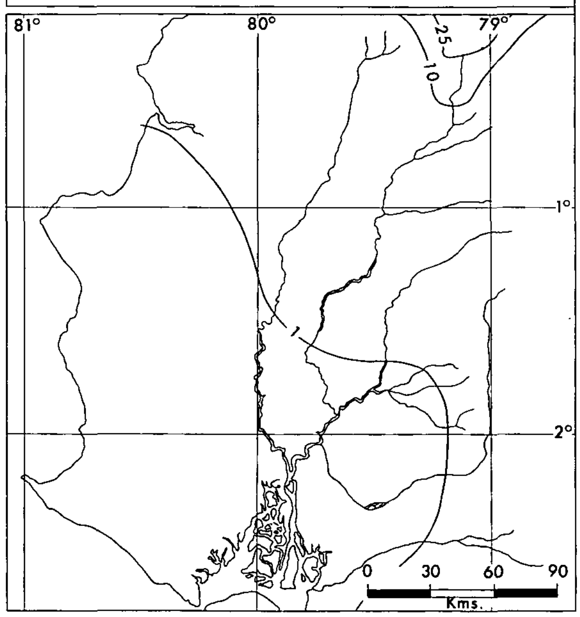


Fig. 4

The effects of orography are also clearly visible on the maps depicting absolute maximum and minimum monthly precipitation. East of the 1,500 mm. annual isohyet, which roughly parallels 79°30' West Longitude, there is a transition from annual moisture deficit, where evapotranspiration exceeds precipitation, to an annual moisture surplus. The rainy season becomes both longer (four months from January through April) and more intense, with values of over 200 mm. per month. Here cloudy conditions prevail during most of the year, a vital factor greatly hindering aerial photography, and even during the dry season rainfall averages in the neighborhood of 25 mm. per month. Although annual rainfall is near 2,000 mm. in the eastern part of this region, agriculture is nevertheless limited by conditions of soil drought, as evapotranspiration exceeds rainfall during at least four months. Near the foothills of the Andes, which extend as far west as Quevedo, precipitation values rise rapidly to 2,500 mm. a year. During five months of the year, January through May, over 300 mm. of rainfall are recorded each month, and even during the "dry" season monthly averages fall between 50 and 100 mm., sufficient for normal plant growth.

The unreliability of rainfall from one year to the next is the principal climatic limitation to agriculture throughout the Guayas Basin region and the adjoining coast, even in areas with average annual moisture surplus. In fact, apart from the environs of Santo Domingo de los Colorados, no part of this area has been exempt from having some month in which no precipitation at all has been recorded. This phenomenon can probably be attributed to the vicissitudes of the off-shore ocean currents and their influence on atmospheric moisture. High precipitation values in the northern portion of the basin are also probably related to inter-tropical front influences.

The monthly distributions of minimum precipitation figures are of special interest in demonstrating the need for primary or supplementary irrigation. Flood problems also require serious consideration in the Guayas Basin area. Floods can be nearly as severe in the southwestern tropical dry region in an exceptionally rainy month as they are farther to the east, where average rainfall is higher. Unfortunately, records are too spotty to be able to work out the cyclical nature of flood and drought, which would be useful for future planning. It appears, nevertheless, that the southern coast experiences a definite rainfall cycle with unusually heavy precipitation every seventh year.

Vegetational indexes of climatic conditions

Variations in long-term climatic conditions prevailing in the Guayas Basin have led to the development of different vegetation physiognomies. These physiognomic differences, which reflect the broad relationships between climate and vegetation, were mapped following the classification system of world plant formations devised by Dr. Leslie R. Holdridge (see Fig. 5). Where climatological data are lacking, physiological adaptations to climatic conditions, such as epyphytism and xeromorphism, as well as the occurrence of known indicator species, serve to provide an indirect measurement of such elements as mean annual temperatures, total annual precipitation and evapotranspiration. These are the elements in the Holdridge classification system which serve as parameters for classifying vegetation into plant formations. The accompanying Ecologic Map of the Guayas Basin (Figure 6), adapted from the Ecologic Map of the Coast and Sierra of Ecuador,1/ thus provides further information on the long-term climatic conditions in the area and furnishes a valuable supplement to the relatively meager climatological data collected in recent years in the Guayas Basin.

A large number of plant formations are encountered in the Basin, additional confirmation of its great climatic diversity. The relative aridity of the southern and southwestern portions of the plain is evidenced by the occurrence of Tropical Dry to Tropical Very Dry plant formations, where potential evapotranspiration is two to four times greater than annual rainfall, respectively. A large portion of the Basin falls east of the 2,000 mm. isohyet within the Tropical Moist Forest plant formation. Although annual potential evapotranspiration in this plant formation is somewhat less than annual rainfall, this is a relationship which does not accurately reflect seasonal moisture deficits that occur due to the unequal seasonal distribution of precipitation.

To the north, the boundary between Tropical Dry Forest and Tropical Moist Forest plant formations marks the zone where a gradual transition from deciduous to evergreen forest types takes place. The low temperatures and high rainfall encountered along the Andean front have brought about the development of Subtropical and Low Montane plant formation types, indicating that precipitation is twice as great as potential evapotranspiration; east of Santo Domingo de los Colorados rain forests are found indicating rainfall four times greater than potential evapotranspiration. Permanent cloudy conditions prevail over these very humid areas near the Andean Cordillera during most of the year. Superficial run-off is voluminous, which in turn has led to exceptionally rapid physiographic erosion.

From the standpoint of humidity conditions the most favorable agricultural areas are those where annual rainfall equals potential evapotranspiration. In the Guayas Plain this occurs in the vicinity of the boundary between Tropical Dry Forest and Tropical Wet Forest plant formations. The unusually marked dry season typifying much of the Basin results in seasonal mosture deficits, however, even where annual rainfall exceeds evapotranspiration rates. In general, the areas suffering considerable moisture deficits, which have pronounced dry seasons, are those that are presently most intensively cultivated.

Geomorphology and Geology

A geologic reconnaissance of the Guayas Basin was carried out as an integral part of the OAS survey. Emphasis was placed on an evaluation of mineral potential, and the soils technician and hydrologist sought to provide basic data on parent material and geomorphology as it would affect agricultural development.

1. Mapa Ecológico de la Costa y Sierra del Ecuador (Preliminary Edition) compiled by O. Vivanco de la Torre and others under the direction of Joseph A. Tosi, Jr., Inter-American Institute of Agricultural Sciences of the Organization of American States, 1963.

Diagram for the Classification of

World Plant Formations or Natural Life Zones

by L. R. Holdridge

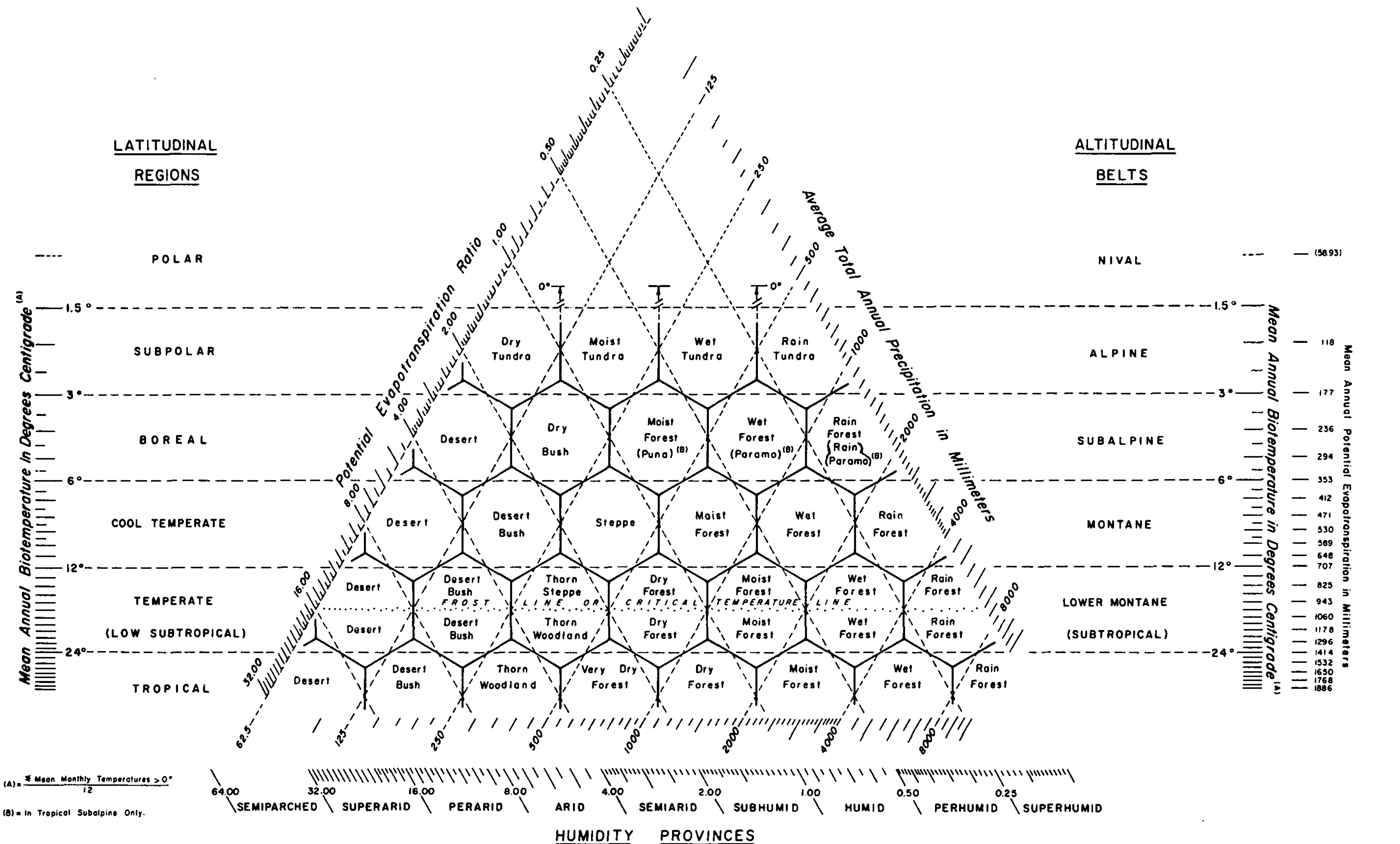


Fig. 5

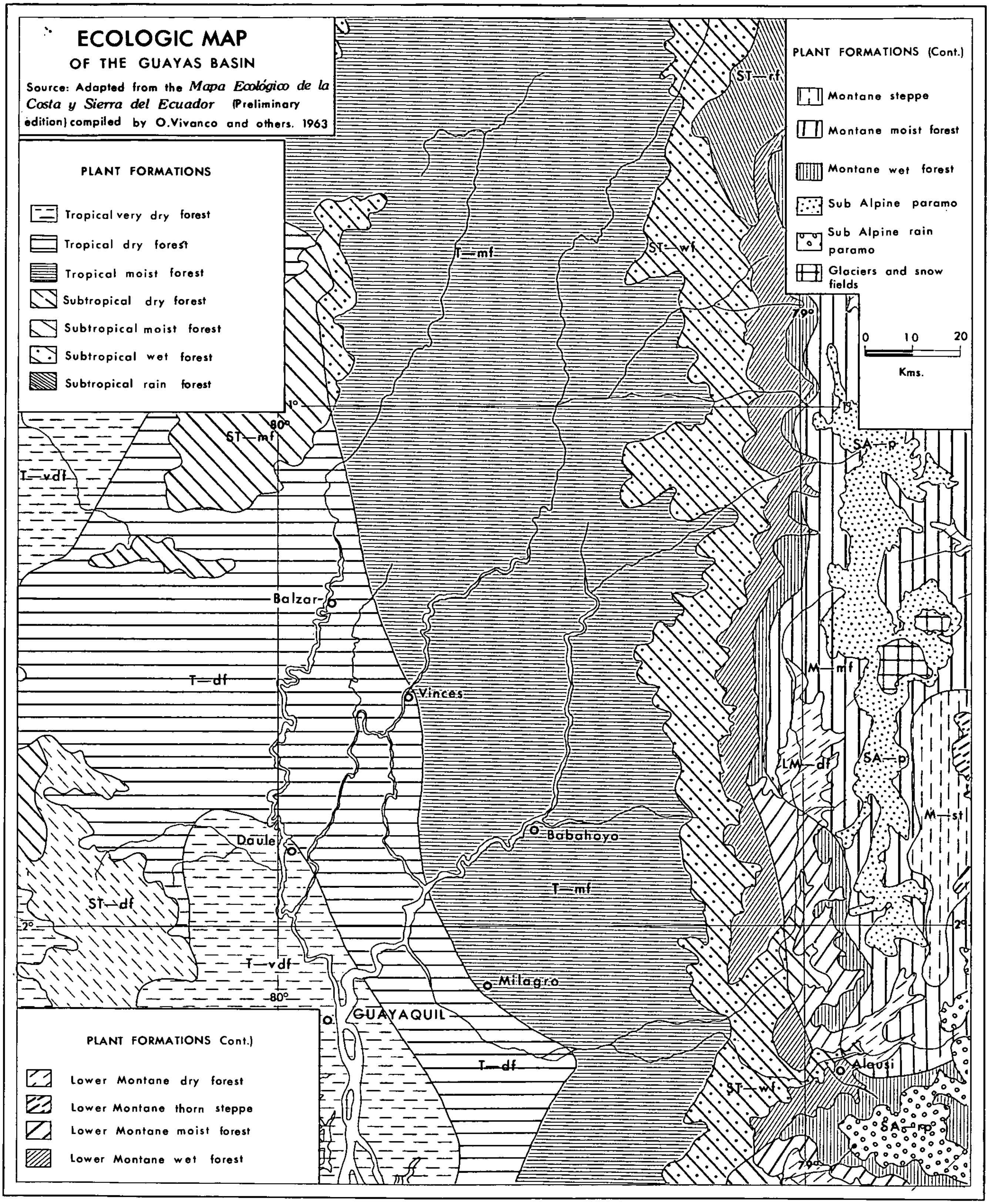

ECOLOGIC MAP
OF THE GUAYAS BASIN
Source: Adapted from the *Mapa Ecológico de la Costa y Sierra del Ecuador* (Preliminary edition) compiled by O.Vivanco and others. 1963
PLANT FORMATIONS
Tropical very dry forest
Tropical dry forest
Tropical moist forest
Subtropical dry forest
Subtropical moist forest
Subtropical wet forest
Subtropical rain forest
PLANT FORMATIONS (Cont.)
Montane steppe
Montane moist forest
Montane wet forest
Sub Alpine paramo
Sub Alpine rain paramo
Glaciers and snow fields
0 10 20
Kms.
PLANT FORMATIONS Cont.)
Lower Montane dry forest
Lower Montane thorn steppe
Lower Montane moist forest
Lower Montane wet forest
ST—rf
ST—wf
T—mf
ST—mf
T—vdf
Balzar
T—df
Vinces
Daule
Babahoyo
ST—df
T—vdf
Milagro
GUAYAQUIL
T—df
ST—wf
Alausi
SA—rp
SA—p
M—mf
LM—df
M—st
1°
2°
80°
79°

Fig. 6

Because most of the area lacked large scale geologic or topographic maps as well as aerial photographs, a considerable portion of the time was devoted to a review of existing geologic materials. Aerial photographs, available primarily in the western part of the Basin, were utilized in the study of geomorphology and in the compilation of the geologic map. The planimetric base map of the area based on the existing 1:500,000 Instituto Geográfico Militar map was corrected where feasible from field observations and interpretation of aerial photographs. In the Andean Mountain Province, geologic contacts were plotted using the Geologic Map of Ecuador (W. Sauer, 1957) as a guide; however, because of the large differences in scale of the two maps, the locations of contacts on the map Geology of the Guayas Basin (Appendix F) are extremely generalized. In the western part of the area contacts are plotted with reference to drainage and are more reliable. No air photographs were available for the central part of the map, and the contacts were plotted using known salient topographic reference features.

Three field trips to various parts of the Basin and an aerial reconnaissance of the northern area were made. As only that part of the area that is along the major highways was readily accessible, contacts were projected without control over great distances. The geologic map shows general areas of particular geologic formations, and, combined with the textual data, provides a basis for geological evaluation.

1. Geomorphology

The Guayas River Basin of Ecuador is characterized by four distinct geomorphic regions. They include the Cordillera de Balzar, the Cordilleras de Colonche and Chongón, the Guayas Plain, and the Andean Mountain Province. These regions are shown on the map of geomorphology of the Guayas Basin (Figure 7).

In the Cordillera de Balzar, the bedrock, which is predominantly marine sandstone and shale, is moderately indurated and dips very slightly to the east. The Cordillera de Balzar, a large maturely dissected plateau whose maximum elevations are about 1,000 meters, forms the divide between streams entering the Guayas Basin drainage system and those flowing westward to the Pacific Ocean. The crest line, which is composed of small peaks and sharp divides, is very sinuous. Remnants of the plateau can be traced southward to Pedro Carbo and westward to a point near Portoviejo. In many places where the sandstone facies is well developed, steep to vertical scarps are formed. Steep-walled valleys, cut in sandstone, are typical of the area south of Santa Ana.

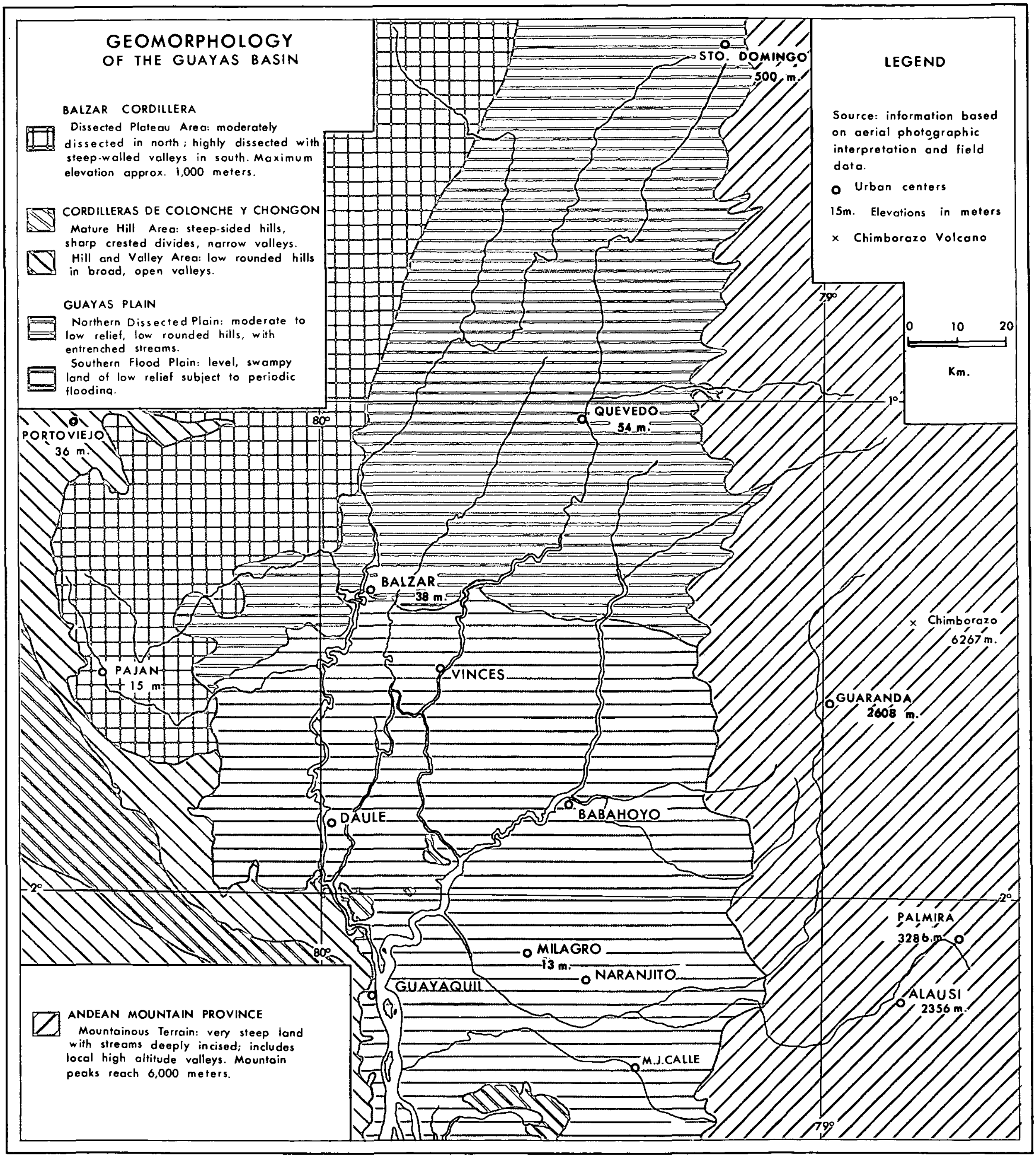
As the area is highly dissected and topographically rugged and steep it is not suitable for extensive agricultural development; however, small-scale farming can be done in some of the larger valley bottoms.

To the west is a lowland merging into the low hills of the Cordilleras de Colonche and Chongón. This lowland is predominantly shale and therefore is relatively less resistant than the neighboring uplands. It is broad and open and has a belt of low rolling hills along its flanks.

The Cordilleras de Colonche and Chongón consist of a linear series of hills whose average elevation is about 1,000 meters, and whose monoclinal structure dips southward at Guayaquil. Generally, the cordilleras arc northwestward parallel to the coast. Cretaceous pyroclastic and marine sedimentary rocks are the oldest rocks exposed; these are overlain by Tertiary sandstone and shale. The crest line of the Cordillera forms the divide for streams flowing into the Guayas Basin and those flowing southwestward to the ocean. Drainage appears to be deeply incised and fairly well integrated. Most of the smaller streams are intermittent, but a few of the major streams flow the year round. The topography is very rugged--valleys are youthful and V-shaped, and summit areas are moderately rounded to sharp and form sinuous divides. The valleys are choked with alluvium but have not been sufficiently widened to form extensive flood plains.

The Guayas Plain is a vast, virtually flat alluvial plain which slopes from Santo Domingo de los Colorados southward to the Golfo de Guayaquil. It is bordered on the east by the foothills of the Andes and on the west by the Cordillera de Colonche, Cordillera de Chongón, and Cordillera de Balzar. At Santo Domingo de los Colorados the plain is at 600 meters elevation, at Quevedo 30 meters, and at Babahoyo 8 meters. It has been formed by the gradual filling in of a longitudinal depression, probably a graben. A series of north-south faults form the eastern limit of the graben along the mountain front. Deep test wells in the vicinity of Pichincha indicate that the floor of the graben is composed of basic rocks. Apparently the floor is inclined as similar rocks appear at the surface from Samborondon southward. The sedimentary rocks that fill the graben-like depression range in age from Miocene to Recent. Coarse constituents are present near the mountain front; finer grained deposits grade out into the center of the basin. Interbedded and (or) admixed are tuffaceous materials resulting from the periodic volcanic activity in the Andes Mountains. The area is drained by numerous streams which compose the systems of the Daule and Guayas Rivers. Periodically during the rainy season parts of the plain from Vinces southward are flooded. Occasionally, severe floods inundate Babahoyo and Milagro. The Guayas Plain may be subdivided into two parts, the northern dissected plain and the southern flood plain. The transition zone between the two is indistinct as one grades imperceptibly into the other. The southern flood plain is characterized by a rather smooth flat surface interrupted only by protruding residual hills such as those near Samborondon. In composition and physical features this part of the plain is typical of a large alluviated area. The northern plain, however, is distinctly different, as it is highly dissected and little if any of its original surface is preserved. Apparently this dissected plain was partially covered several times by volcanic ash, some of which was reworked and filled the former depressions and valleys, which resulted in a nonintegrated minor drainage system. Recently the plain has been gently uplifted and the major streams have been incised. At Pichincha the Río Daule is at least 30 meters below the upland surface; at Quevedo, the Río Quevedo is about 10 meters below.

The Andean Mountain Province consists of a generally north trending mountain range whose western flank forms the border of the Guayas Plain. The mountains are very high, have steep-sided, deep major valleys and are intricately dissected by the numerous minor streams. Major structural features are north-trending faults along which various igneous, metamorphic, and sedimentary rocks have been elevated. Superimposed on this structurally complex area are volcanic cones. Chimborazo, the highest cone in Ecuador, is 6,267 meters in elevation and its peak is capped by several active glaciers. Other high peaks glaciated during the Pleistocene are characterized by the typical U-shaped valleys.



GEOMORPHOLOGY
OF THE GUAYAS BASIN
BALZAR CORDILLERA
Dissected Plateau Area: moderately dissected in north; highly dissected with steep-walled valleys in south. Maximum elevation approx. 1,000 meters.
CORDILLERAS DE COLONCHE Y CHONGON
Mature Hill Area: steep-sided hills, sharp crested divides, narrow valleys.
Hill and Valley Area: low rounded hills in broad, open valleys.
GUAYAS PLAIN
Northern Dissected Plain: moderate to low relief, low rounded hills, with entrenched streams.
Southern Flood Plain: level, swampy land of low relief subject to periodic flooding.
ANDEAN MOUNTAIN PROVINCE
Mountainous Terrain: very steep land with streams deeply incised; includes local high altitude valleys. Mountain peaks reach 6,000 meters.
LEGEND
Source: information based on aerial photographic interpretation and field data.
Urban centers
15m. Elevations in meters
× Chimborazo Volcano
0 10 20
Km.
STO. DOMINGO
500 m.
QUEVEDO
54 m.
PORTOVIEJO
36 m.
BALZAR
38 m.
PAJAN
15 m.
VINCES
GUARANDA
2608 m.
Chimborazo
6267 m.
DAULE
BABAHOYO
MILAGRO
13 m.
NARANJITO
GUAYAQUIL
PALMIRA
3286 m.
ALAUSI
2356 m.
M.J.CALLE
80°
79°
1°
2°

Fig. 7

Within the Andean Mountain zone is a narrow north trending graben-like trough called the inter-Andean basin. The area from Ambato to Alausi lies within this basin. Along the axis of the basin, the Río Alausí has cut a narrow deep canyon whose steep walls expose a thick sequence of volcanic rocks and ash and thin interbeds of alluvium. Landslides are common along many of the steep-walled valleys.

The schematic cross section (Fig. 8) shows the major rock units and their topographic relationships.

2. Geology

Sedimentary rocks

Pre-Cretaceous (Paleozoic?) rocks consist of a thick series of shales and siltstones that have been slightly metamorphosed to argillites and very low rank slates. Gliding planes have formed but the definite sedimentary character of the rocks has not been obliterated. The rocks occupy a highly deformed belt extending from Guaranda southward to General Elizalde. Several outlier hills are formed by blocks of the rocks elevated by transverse faults in the coastal plain southeast of Guayaquil.

Cretaceous rocks consist of a complex sequence of fine-grained marine sedimentary rocks interbedded with silicified pyroclastic rocks and lava flows. This sequence, termed the Piñon Formation (P-fm)2/ forms a resistant ridge trending west to northwest from Guayaquil. Younger marine fine-grained sedimentary rocks and limestone overlie the Piñon Formation and are called the Callo and Guayaquil formations (C & G fms.).2/ Tuffaceous facies with silicified or cherty layers occur throughout these two formations.

The Tertiary rocks have been divided into many formations, mainly for purposes of detailed mapping in the petroliferous areas to the west.

The Stratigraphic Table of the Coastal Tertiary (Table 1) shows the various formations and their stratigraphic relationships. For the purpose of the geologic map of the Guayas Basin accompanying this report, however, some of the lower Tertiary units have been grouped according to age equivalence, whereas within the Miocene two units have been differentiated (primarily because of the marked lithologic change discernible on the aerial photographs). The oldest Tertiary rocks are the Eocene limestones of the San Eduardo Formation. They have an average thickness of 60 meters along the southwest dip slope of the Cordilleras de Colonche and Chongón, and consist of light-gray to medium-gray fine-grained limestones, locally siliceous and cherty, in irregular beds as much as 0.3 meter thick. The limestone contains a high ratio of CaO and is an important source of lime for cement. In the lowland plain west of Guayaquil a sequence of medium brownish-gray shales, also of Eocene age, overlies the limestone. In the Jipijapa Basin area, particularly west of Portoviejo, Eocene strata are more arenaceous. Oligocene

2. The position of these formations have been indicated by abbreviations on the stratigraphic column in the legend of the map Geology of the Guayas Basin.

strata consist of a thick sequence of drab brownish-gray and yellowish-brown clayey shales containing local zones of siltstone or silty shale. The rocks form the lower valley floors and slopes and subdued hills in the area near Portoviejo. The Miocene sedimentary rocks include a lower shaly facies, the Charapoto and Onzole Formations; and an upper sandy facies, the Progreso Formation. The shales are clayey and contain random interbeds or lenses of gray fine-grained limestone. These beds also form the lower valley slopes and floors in the area near Portoviejo and Santa Ana. The overlying sandstone is medium to coarse grained and contains local thick crossbeds of conglomeratic sandstone.

The sandstone beds are relatively resistant and form steep slopes to nearly vertical cliffs along the crest of the Cordillera de Colonche in the central northwest, and form lower hills in the southwestern part of the area. The Progreso Formation extends along the divide of the Cordillera de Balzar forming the northwestern boundary of the Guayas Basin. The limits of the Progreso Formation along the eastern slope of the Cordillera de Colonche have been delineated mainly by aerial photographic interpretation without benefit of extensive field checking and are therefore not very reliable. In several of the deep test holes in the interior Guayas Basin, Miocene strata have been penetrated; presumably these are lateral equivalents of the Progreso, Charapoto and Onzole Formations.

Sedimentary rocks of Quaternary age include the unconsolidated vast flood-plain deposits of the Guayas Basin and gravels, conglomerates and sands along the valley floors of the Andes Mountains. Within the Guayas flood plain the coarse conglomerates and gravels are generally within a few kilometers of the foothills at the base of the western flank of the Andes Mountains, whereas the finer grained sands and silts are in the central part of the Basin. Fine-grained constituents also prevail along the western edge of the flood plain at the base of the Cordillera de Colonche, as the parent materials are fine grained. Near Guayaquil, however, the more resistant rocks of the Cretaceous locally furnish coarse conglomeratic constituents. Intermixed with the Quaternary surficial deposits are layers of volcanic ash. Some of the younger ash falls have been admixed and integrated with other fine-grained deposits and form a distinctive soil (see the Pichilingue Association on the map Soils of the Guayas Basin in Appendix F).

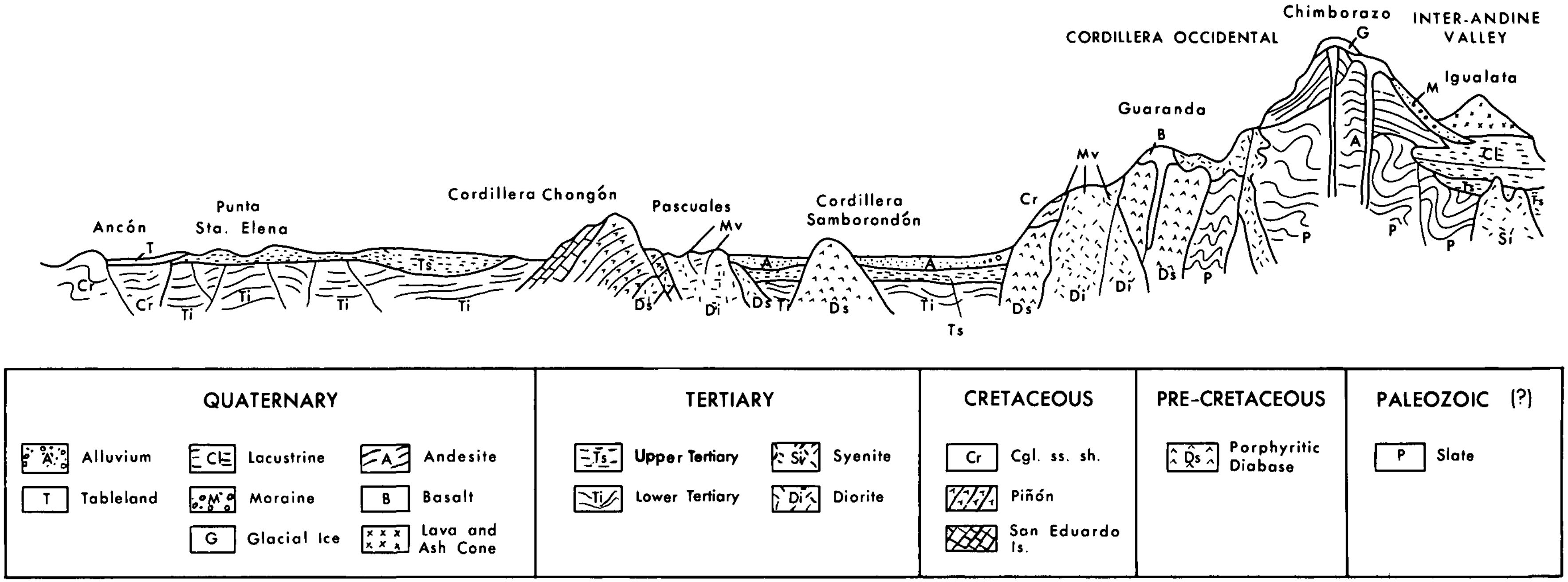
Igneous rocks

Both extrusive and intrusive varieties of igneous rocks occur within the Guayas Basin. Diorite, syenite, granodiorite and diabase are the most common types of intrusive rocks. Gray porphyries, dark-gray basalts, and various types of ejecta (ash, cinder, and pumice) are the common types of extrusive rocks. Within the Piñón Formation near Guayaquil are basic flows and pyroclastics which have been intruded by diorite. A prophyritic diabase occurs at Samborondon. Several other diabase rocks of the Piñón Formation crop out a few kilometers west of Portoviejo. No igneous rocks have been recorded within the eastern Guayas Plain. The western flank of the Andes Mountains is composed of many varieties of igneous rocks, both intrusive and extrusive. In general, a belt of dark-green diabase occurs along the foothills and by faulting is in juxtaposition with Cretaceous and older sedimentary rocks. Several diorite stocks and one large mass of granodiorite have been emplaced

Fig.8

SCHEMATIC GEOLOGIC PROFILE OF ECUADOR*

COMPILED BY DR. W. SAUER
MODIFIED BY R. MORRIS



Mv = Mineral vein

HORIZONTAL SCALE 1:1,000,000

*Modified from *Contribuciones para el Conocimiento del Cuaternario en el Ecuador* Walter Sauer, 1950 along this western zone. The inter-Andean basin is composed of a thick sequence of porphyritic lavas and volcanic ash, cinders and pumice. Lavas characteristic of the volcanic cones (e.g., Chimborazo) range from dark glassy to light prophyritic and are usually andesitic. The volcanoes within the Guayas Basin are considered extinct although the active volcano Sangay is only 50 km. east of Guamote. The greatest period of volcanic activity was during the late Tertiary and early Quaternary. The diorite, diabase, and syenite intrusives were emplaced during the Late Cretaceous and possibly as late as early Tertiary. The faults associated with this magmatic phase were the loci of sulfide mineralization. The faults are so numerous and complex that no attempt was made to show them on the geologic map. One small area of pronounced faulting discernible on the photographs has been shown near Guamote.

3. Minerals

Economic geology

The economic resources within the Guayas Basin include some mineral deposits and a considerable variety of constructional materials.

During the late Tertiary orogeny, which thrust up the western flank of the Andes Mountains, a series of generally north-trending faults were formed, and large masses of igneous rocks, mainly granodiorite, diorite and syenite, were emplaced. Metallic sulfides and associated minerals were deposited by hydrothermal solutions along the faults. The resulting mineralized areas include, from north to south: (1) La Plata - copper, lead, zinc, gold and silver in a gangue of quartz and barite; (2) Macuchi - copper, lead, zinc, gold and silver, in a gangue of quartz and barite; (3) Talagua - molybdenum in very small veins with accessory zinc and copper; and (4) Bucay - copper, gold and silver. Pyrite is abundant in all the metallic sulfides. Native sulfur occurs at Alausi and Tixan but it is probably associated with the younger episodes of volcanism.

During the period of study by the OAS Mission, the only mine in operation in the Guayas Basin area was that producing sulfur at Tixan. Former extensive workings in this mine have been abandoned; machinery has been dismantled and removed. Today only a few miners using hand tools are high-grading small amounts of sulfur, under an agreement with the Asistencia Social. Much material probably containing as much as 30 percent sulfur is being stockpiled near the open excavations. The mine at Macuchi has been abandoned and the company reports that commercial-grade ore is exhausted. La Plata has also been abandoned for several years, but in August 1963, a new concession was being solicited in the Ministerio de Fomento, Dirección de Minas e Hidrocarburos. The area has been set aside as a national mineral reserve, however, and no concessions will be granted within it until a proposed geologic study has been completed and its findings released to the public.

At Salinas, north of Guaranda, several springs that appear to be related to the north-trending faults yield saline waters from which table salt containing a small amount of iodine is recovered. The salt is concentrated by solar evaporation in open basins near the springs or in large metal tubs heated by wood fires in crude fireplaces. Annual production probably does not exceed 25 tons.

Hematite containing minor amounts of magnetite occurs as loose boulders in stream channels along the eastern part of the Cordillera de Colonche. The source of these is believed to be along the contact of the Piñón and Callo Formations. No deposits of commercial value have been found to date.

In stream valleys along the foothills of the western flank of the Andes placer deposits of gold have been worked for many years. Large operations have not been very successful, although individual manual mining ventures by local residents have succeeded.

Construction materials

Resources of various construction materials within or very near the Guayas Basin include limestone, gravel, cinder, sand, riprap, crushed stone, building or dimension stone, and clay for brick and tile.

Lime for cement is obtained from a large quarry in the San Eduardo limestone a few miles west of Guayaquil, and from a Cretaceous(?) limestone in the area northwest of Riobamba at the village of Calpi. The Chimborazo Cement Co. operates the mine and plant at Calpi; the Rocafuerte Co. operates the quarries and plant at Guayaquil. Both areas have large reserves of limestone suitable for making portland cement. Each locality is serviced by road and railroad.

Sand and gravel deposits are widespread, particularly along the major rivers which descend the western flank of the Andes and those that have cut back into the inter-Andean Basin. Within the inter-Andean Basin some deposits are perched high on old fluvial terraces. The coarse constituents of all deposits are composed of various igneous rocks that have been thoroughly rounded by stream action, are generally fine grained, rather durable, and are suitable for concrete aggregate. In a perched fluvial deposit near Ambato the material is screened and used for road metal on the new Pan American Highway. In road work on the new Santo Domingo de los Colorados-Quevedo Highway local gravel is used, apparently without screening, as a base for asphalts. Within the city of Guayaquil much of the concrete aggregate being used is unwashed or unscreened stream gravel.

Riprap and road metal is obtained from various formations. Near Guayaquil and Alfaro the rounded hills of Cretaceous rocks (Piñón and Guayaquil Formations) are quarried for fill aggregate. The diabasic rock quarried at Piedrahita (north of Guayaquil) is highly weathered and easily quarried with hand tools; because of its susceptibility to rapid chemical weathering, however, it is not the best type of stone to use for road metal. Within the inter-Andean Province a large variety of rocks, mostly of volcanic origin, are available for use as riprap.

The dimension stone industry is not very advanced, probably because of the considerable expense of heavy power equipment needed for quarrying, cutting, and polishing. There is, however, a growing interest in handcut raw stone for construction of intricately interlocked blocks for walls around homes and decorative façades on office buildings. Various igneous rocks are used for this, including porphyry, granodiorite, syenite, and dark extrusive rocks. The porphyries work easily but are frequently highly weathered and of lower durability. Near Guayaquil the Piñón Formation and various basic intrusives make attractive dimension stone. Along the front of the Andes and in the inter-Andean Basin many durable and colorful rocks are available for dimension stone.

Clay deposits are of three major types: those derived from volcanic ash, those accumulated along the flood plains of the numerous rivers, and those of clay deposits in older (Tertiary) sedimentary rocks. In the inter-Andean Basin the almost ubiquitous cover of volcanic ash provides a large resource of ash clay. It is the universal building material for adobe walls, blocks and surfacing. When it is fired in ovens at moderate temperatures a low-grade red brick is produced. Throughout all of the Andean villages or towns there may be found numerous small adobe and brick plants. Along the major rivers of the Guayas Basin, such as Río Daule or Río Babahoyo, there are numerous small plants manufacturing adobe or fired bricks from the clay deposits. In the Cordilleras de Colonche and Chongón, Tertiary formations such as the Tosagua, Subibaja and Charapoto, which contain much clay, are used for local manufacture of adobe and fired brick. About 20 km. west of Guayaquil is an abandoned quarry in Eocene shales that was used for clay. There are reportedly two minor sources of kaolin--one at Bilovan, the "La Florida" mine, and the other near El Corazón, the "Gran Colombia." Both deposits appear to be related to deep weathering or alteration of igneous masses, though direct field data are lacking. Within the Basin reserves of clay for medium- to low-quality tile, brick, and other ceramic products appear adequate. There are no known reserves of high quality refractory clays, though detailed descriptions of Tertiary sedimentary rocks mention occurrences of bentonite without reference to their probable aerial extent or suitability.

In the Andean Mountain Province, scattered about the base of the large volcanoes (Chimborazo, etc.) and extending out over the inter-Andean Basin, are numerous beds of volcanic cinders and pumice. Some of these have been used as aggregate for cement-block manufacture though in a rather crude unwashed state, and the blocks are therefore quite fragile. If the raw material were refined it possibly could be used in making lightweight pre-cast cement acoustical panels and blocks.

Petroleum and gas

For many years the Guayas Basin and the coastal areas of the Cordilleras de Colonche and Chongón have been studied, mapped and tested for petroleum. So far the only economic deposits have been on the western side of the Cordillera de Colonche divide, outside the Guayas Basin. Continued production from the western fields (such as Ancon) has been sufficient to supply about half of the national requirements. Deep holes drilled within the Guayas Basin, as at Pichincha, have encountered a basic igneous complex at depths of as much as 2,000 meters. The area appears to lack the source beds in favorable structural relationships as at Ancón. Among the many companies that have participated in the geological studies are Anglo Ecuadorian, Tenec (Tennessee Oil & Gas), California Oil Co., International Ecuadorian Petroleum Co., and the Manabí Exploration Co.

No coals are known within the Guayas Basin. The country's supply comes from mines at Biblian, Nabon, Loja and Malacatus in the southern part of Ecuador.

The lithologic, economic, engineering, hydrologic, and geomorphic data of the area are summarized in Table 2.

Soils

As in the case of the geologic investigation, the exploratory study of the soils of the Guayas Basin is based on a review of existing data relating to the area, interpretation of available aerial photographs, and field investigation. As only two months were spent in the field, actual field checks could only be made of the more accessible areas along roads and trails. Consequently, many of the soil demarcations are based on extrapolations of a limited number of field checks, profile observations and soil samples from pits and by auger.

Descriptions of different soils associations and their formation as well as pertinent observations related to land use and land capability are presented. A profile description of a representative soil of 9 of the 12 associations is found in Appendix C, Profiles 1 through 9.

1. Factors that have Influenced Soil Development

Among the soil forming factors, those which have been most influential in the development of the soils in the area are climate, parent material, time, slope, and the action of water as a function of relief and climate. In greater detail these include the following:

Climate

Over the greater part of the Guayas Basin at lower elevations, humid to dry tropical climatic conditions prevail. Mean temperatures are around 22-25 degrees C., and average annual rainfall ranges from 200 to 3,000 mm. per year. A pronounced dry season occurs from June to December, most of the precipitation occurring in the remaining six-month period. The fluctuations in the status of soil moisture, compounded in places by seasonal inundations, have affected soils development and plant growth. Also it should be noted that in humid sites, where temperatures approach 25 degrees C., the rate of organic matter decomposition nears the rate of accumulation, which often leads to soil acidity and a lowering of base exchange capacity when deforestation halts additions of organic matter.

Cooler temperatures accompanying higher elevations in the Cordillera not only lower the rate of organic matter decomposition but make rainfall more efficient, creating in places more humid conditions than exist in the lower plain.

Parent material

Soils in the Guayas Plain are derived from Tertiary as well as more recent sediments originating from basic intrusive and extrusive rocks, which

Table 1

STRATIGRAPHIC TABLE CF THE COASTAL TERTIARY
(Modified slightly from Sauer, 1957)

Period	Series	Stages	GUAYAS: Ancón Oil Field: Formations	GUAYAS: Ancón Oil Field: Thickness (in meters)	GUAYAS: Chongón and Colonche Cordilleras, Progreso and Puna Basins: Formations	GUAYAS: Chongón and Colonche Cordilleras, Progreso and Puna Basins: Thickness (in meters)	Daule-Quininde River Basin: Formations
Quartenary			Tablazos	5-40	Tablazos	20-60	Alluvium
Tertiary	Pliocene				Puná, Pre-Puná		Pliocene-Pleistocene
	Miocene	Upper			Lechuza Placer Cerro Malo		Miocene
		Middle			Progreso	Variable, up to 2000	
		Lower			Subibaja	550	Transgression
	Oligocene	Upper			Dos Bocas / Miogypsian Limestone		
		Middle			Dos Bocas Rodeo, La Cruz	1000-2000	
		Lower	Ancón Point	100-200	Zapotal Posorja	1500-3000	
	Eocene	Upper	Seca Shales	300	Salanguilla Ancón Group	1000	Daule Subterranean "Plateau"
		Middle	Socorro beds Clay pebble beds Middle grits	300-500	San Eduardo transgression	2800	
		Lower	Atlanta Shales Atlanta Sandstones	800 1100	Engabao Chanduy	1000	
	Paleocene		San José Shales San José Sandstones	120 1055	Estancia	2000	
Cretaceous	Upper	Danian					
		Maestrichtian			Guayaquil	500-650	
		Lower Senonian Turonian Cenomanian			Callo Calentura	3000	
	Lower	Neocomian			Piñon		Piñon

have washed down from the Cordillera front in the east. In the western half of the plain, soils have formed over sediments derived from the sandstones, shales and limestones forming the dissected plateau and low hills of the Cordilleras of Balzar, Colonche and Chongón. The nutrient status of the alluvial soil constituents is therefore variable. Sediments generally trend from basic in the eastern half of the plain to acidic in the center and basic or calcareous in the western portion. Basic volcanic ash and other ejecta have been deposited or washed down to the Guayas Plain in geologically recent times, a thick mantle having been formed in places along the flat piedmont adjacent to the Andean foothills.

Seasonal stream depositions of sediments originating from basic volcanics and igneous rocks serve to enrich the eastern half of the alluvial plain. It is generally in the eastern and northeastern portion of the Guayas Plain, therefore, that soils develop over relatively nutrient-rich parent materials such as feldspar sands and the weathering products of ferro-magnesian minerals. It is noteworthy that where these parent materials occur rainfall is heaviest, whereas over the less fertile clay soils in the west and southwest, sub-humid or arid conditions prevail. In areas of heaviest rainfall on the plain, leaching of soils is pronounced and conditions are favorable for the eventual development of zonal latosols.

Older materials, primarily old volcanics and detritus from volcanic and granitic masses, can be found where the recent deposits are thin, such as in eroded places, especially on the western edge of the Basin. The alluvial and hydromorphic soils derived from these old materials are concentrated in the lower Daule and Guayas River areas.

Vegetation

Vegetation has not had sufficient time to become a determinant factor in soil development over much of the area since soils or physiography are relatively young. Remaining forests are tropical evergreen broadleaf or deciduous broadleaf for the most part. Some mangrove forests exist in the south near the mouth of the Guayas River. Over some latosols (the Oro Association) the vegetative cover is both evergreen and deciduous broadleaf forest.

Relief and water action

Rivers have cut out channels of various depths through the mountains and have worked and re-deposited sediments in the flood plain of the Guayas River and its tributaries. A wide range of soils in various stages of development occur in the Guayas Plain, being influenced by seasonal flooding, slight differences in relief and proximity to the hills and mountains on the east and west. The lower areas of the Plain are typically hydromorphic, although contiguous soils on slightly elevated topography can be well drained.

In the northwest portion of the Basin, rolling topography and other conditions have favored the development of zonal latosols.

Along the Andean front and the higher slopes, steep relief prohibits the development of a soil profile, and erosion appears to exceed soil profile development. Intense weathering action, together with superficial erosion, would create a situation propitious to a continuous replenishment of plant nutrients in soils over the basic rocks which underlie this steep topography.

2. Mapping Criteria

The soil association is the basic mapping unit utilized in this study. A soil association includes one or more soils series that may or may not be related morphologically but are geographically near to each other and have similar management requirements. Because of the mapping scale used in this study, unrelated soils may be included in a mapping area but descriptions do not apply to them. An example of these unrelated soils would be those occurring on a natural levee adjacent to soils of backwater areas.

One important soils series of each association is described by profile and other characteristics which influence soil management (See Appendix C). The data as presented are for a particular soils series and are applicable to the soil association in general.

The soil associations may be grouped into additional classifications with the final grouping being zonal, intrazonal and azonal, depending on degree of profile development. The classification of Guayas Basin soils is shown in Table 3.

3. Zonal Soils

The zonal soils are those exhibiting definite developed profile characteristics. The Guayas Basin includes many zonal soils buried under a meter or more of recent volcanic material. Unless the zonal characteristics are the primary factor influencing agriculture, these soils are not considered zonal.

Oro Association (O)[3]

The latosolic soils of the western Guayas Basin are mapped as the Oro Association and represented by San Miguel Clay. Other latosolic soils are found but these are included in other associations since they represent too small an area to map separately. The association will include a wide variety of related and non-related soil series. The distinguishing characteristics of this association are slopes of over 60 percent and location on the western edge of the Guayas Basin.

3. Capital letters in parenthesis after the association name are those used to identify the soil association mapping units on the map Soils of the Guayas Basin in Appendix F.

Table 3

OUTLINE CLASSIFICATION OF THE SOILS OF THE GUAYAS BASIN

Soil Groups[a]	Association	Mapping Symbol	Representative Soil Types
Zonal Soils			
Latosolic	Oro	O	San Miguel Clay
Brown Loams	Balzar	B	Balzar Clay Loam
Gray-Calcic	Ayora	A	Ayora Clay
Intrazonal Soils			
Black Clays	Daule	D	Daule Clay
Hydromorphic	Vinces	V	Vinces Clay
Azonal Soils			
Alluvial	Naranjito	N	Naranjito Fine Sandy Loam
Recent Volcanic			
Andean foothills	Maná	M	Maná Fine Sandy Loam
Andean valleys	Chimbo	C	Chimbo Loam
Level	Pichilingue	P	Pichilingue Loam
Paramo	Zumbagua	Z	Chimborazo Loam
Andean hills	Tambo	T	----
Lithosols	Riobamba	R	----

a. Soil group designations are not conclusive due to lack of sufficient data for proposing established nomenclature.

The soils of the Oro Association were mapped by Frei[4] and Miller[5] as brown loam and gray non-calcic. Either classification might apply to limited small areas but does not describe the predominating red, brown and yellow clays. These soils have developed on a wide variety of parent materials including limestone, sandstone and shale mostly of Tertiary origin. They occupy slopes of 60 percent and steeper as cut by Pacific Coastal streams and tributaries of the Daule River. The highest pass on the present roads is at 570 meters, with some peaks rising a few hundred meters higher. The soil extends to sea level near Guayaquil.

Balzar Association (B)

These brown and gray-brown soils occur on low ridges and rolling hills of the western Guayas Basin on both sides of the Daule River north of the flood plain. The predominant slopes are 10 to 60 percent, but flat lands occur as isolated pockets either on top of ridges or in depressed areas. Steeper slopes are mapped within other associations. Frei has mapped these soils as brown latosols, and Miller as brown loam and gray non-calcic. They are in reality a transition zone between the recent volcanic soils and the Oro latosols.

The parent material is similar to that of the northern limits of the Oro Association plus surface deposits of recent volcanic ash usually no more than a few inches deep. Elevations range from 80 meters in the south to over 600 meters above sea level west of Santo Domingo de los Colorados. Rainfall ranges from less than 2,000 mm. per year in the south to over 3,000 mm. per year in the northeast. Because of the excellent internal and external drainage the dry season is often very severe. Crop yields are satisfactory only in the wet season.

Some corn, cacao, coffee and bananas are grown but they are generally unsatisfactory.

Ayora Association (A)

This association includes the grayish calcareous clays of the west plain of the Daule River with slopes of 0 to 10 percent. These soils are not subject to flooding and are water saturated only during the wet season. They occupy gently rolling hills less than 100 meters above sea level and differ from the Balzar Association in that they lack the surface deposit of recent volcanic ash and are often calcareous. Frei includes these soils in the Regur classification, whereas Miller uses the term dark gray calcic. The pH of the surface is near 7.0 and may reach 9.0 in certain areas.

Growth is vigorous during the wet season but trees and shrubs are barren in the dry season and even grasses have difficulty surviving. Pasture is excellent during the wet season and some rice is grown.

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4. Frei, Erwin. Informe al Gobierno del Ecuador sobre Reconocimiento Edafológico Exploratorio, FAO, Rome, No. 585, 1957.
5. Miller, E.V. Ecuadorian Soils and Some of their Fertility Problems, Thesis, Cornell University, 1948.

4. Intrazonal Soils

These soils have failed to develop a regular profile because of a water table at or near the surface during three to 12 months of the year. They lie in the flood plain of the Guayas River and its principal tributaries.

Daule Association (D)

This group of soils includes level to nearly level clays on both sides of the Daule River and extending to the lower reaches of the Guayas River. A high content of iron and manganese with deposited organic matter contributes to a black surface soil when wet. The elevations range from below high tide in the mangrove area to 60 meters above sea level near Palestina. Salinity from tides is a problem in the lower Guayas River and as much as 65 km. up the Daule River. The land is almost level and external drainage is poor. The fertility is generally good and the pH slightly alkaline. Frei has mapped these soils as black alluvial, while Miller includes them with gray non-calcic soils.

The alluvium which forms these soils comes from both the Daule and Babahoyo River systems but includes the finer material since much of the silt has already settled out in the upper flood plain. The Daule River sediments are the largest contributor to the black soils. Few crops are suitable, although rice produces excellent yields.

Vinces Association (V)

This group of soils is differentiated from the Daule Association by reason of parent material. They are both hydromorphic soils with poorly developed profiles and a blue-gray mottled zone at or near the surface.

The Vinces Association is derived from recent volcanic material brought down by the Babahoyo River. The silt and sand have usually been deposited in the Naranjito Association so that clay is the predominating fraction of the Vinces Association. The pH is slightly acid but neutral soils are common. Slope varies from 0 to 25 percent. The elevation ranges from sea level to 60 meters above sea level and the hydromorphic soils exist as depressed areas between tongues of the well drained alluvial soils at slightly higher elevation. The map separation is schematic, not delineated.

Frei mapped the recent alluvial soils of the Naranjito Association with the hydromorphic soils as "wet alluvial soils." Miller also made no map separation between the alluvial soils and hydromorphic. Both authorities recognized the difference in management. Hardy 6/ points out the close relationship and states that: "the precise conditions and circumstances that differentiate the 'good' from the 'bad' alluvial hydromorphic soils ... are not certainty ... but in general it appears that drainage conditions which control soil aeration constitute the chief factor."

6. Hardy, Frederick. Report on a Visit to the Riverine Belt of Ecuador, Turrialba, Inter-American Institute of Agricultural Sciences, 1960

Rice gives excellent yields during the dry season. Protection from flooding should make it possible to grow a wide variety of adapted crops such as sugar cane or pasture.

5. Azonal Soils

Azonal soils are those that have no profile development. Within the Guayas Basin this includes recent alluvial and volcanic soils and lithosols. The recent volcanic soils are here further separated on the basis of altitude and relief.

Naranjito Association (N)

This association includes all alluvial soils except hydromorphic unless the alluvium exists in isolated areas such as stream bottoms or river outwash where it is mapped with contiguous soil.

The soil mapped as Naranjito Association consists of brown alluvium derived from recent basic volcanic materials. It may or may not be subject to flooding during the wet season but in all cases is well drained internally and a gray or blue mottled layer, if present, exists below one meter. Slopes vary from 0 to 10 percent and the pH is near neutrality.

The soils can be used for all adapted crops such as rice and corn. Perennial and semi-perennial crops such as sugar cane, bananas, cacao, etc., do well on the soils not subject to flooding. Flood control of the alluvial soils will be considerably easier than for the contiguous hydromorphic soils.

Maná Association (M)

The relief of the Guayas Basin changes sharply from the relatively flat plain to the Andean foothills area with 20 to 80 percent slopes mapped as the Maná Association. This break has a north-south orientation in the Basin. The Maná Association is from five to 20 km. wide east of which another sharp break in slope, with slopes of over 80 percent, occurs. The elevation of Maná Association is 200 to 1,000 meters above sea level. The surface consists of recent volcanic materials which may be two to 20 or more meters in thickness overlaying older soils or bedrock. These are considered to be recent volcanic soils, although Frei mapped them as yellowish-red latosols or transition hydrolitic latosols, Miller made no separation but included them with contiguous soils.

The land is being used for coffee and a variety of subsistence crops such as corn, bananas, oranges, etc. With the exception of tree crops such as coffee, forest may be the best use for these soils.

Chimbo Association (C)

The Andean valleys consist of plateau-like areas above 2,000 meters elevation. Slopes may be moderate but will usually be from 10 to 60 percent. The soil is of recent volcanic origin, less weathered than the soils at lesser altitudes. The soils tend to black or gray with little profile development, although a white or light gray layer about one meter from the surface is common. Frei separated these soils into Red Mediterranean and Brunisem, while Miller mapped them somewhat differently as Moist Sierran and Dry Sierran.

A wide variety of crops such as corn, barley, wheat, potatoes, broad beans (habas) and pasture are grown but the combination of high elevation, steep slopes and population density make this an area of subsistence farming.

Pichilingue Association (P)

The recent volcanic soils of the central Guayas Plain lie level to gently rolling with 0 to 5 percent slopes. Elevations range from 20 to 650 meters above sea level. These lands lie on both sides of the Quevedo River from a few kilometers north of Vinces to Santo Domingo de los Colorados.

The eastern limit is a well defined line at the foothills of the Andes mountains as represented by the Maná Association, and the western limit as an indefinite transition area of the Balzar Association. The southern limit is determined by the water worked area of the Naranjito Association and continues northward into the drainage basin of the Esmeraldas River.

The recent volcanic material has older soils at depths of two to 30 or more meters. Little profile development can be seen. Frei mapped these soils as Humic Latosolic Regosols, whereas Miller used the term Brown loam and Gray-brown loam.

All adapted annual and perennial crops can be grown with excellent results, although some water deficiency is found, particularly in the southern part of the association.

Zumbagua Association (Z)

This association includes all soils above 3,000 meters elevation to the snow line plus some at lower elevations, which in their natural state are páramos. The soils are of volcanic origin and have a low bulk density. Although generally of the same age as other recent volcanic soils, they are less weathered because of the low temperature and high altitudes. The land may be level or have slopes of as much as 80 percent.

Frei has called these soils black Andean, while Miller uses the term black páramo.

These soils are used principally for pasture, but crops such as barley, broad beans, etc. are grown up to nearly 4,000 meters above sea level.

Tambo Association (T)

This Association of Andean hill soils lies between 1,000 and 3,000 meters or more above sea level. Slopes are extremely steep, being 80 percent or more. Although some flatter areas are mapped within this association, it is only intended for land with slopes of over 80 percent. Because of the steep slopes, it was impossible to determine a profile representative of the area. Red and yellow clays are intermixed with black and brown volcanic materials as well as many kinds of rocks, pumice, etc. Landslides and erosion have intermixed the soil materials so that any generalization is impossible.

Frei mapped these soils as "transition hydrolitic latosols," while Miller used the term "soft humic forest soils."

Little use is made of the land except for forest, although subsistence farming is practiced on the more gentle sloping land included within the area.

Riobamba Association (R)

The Association includes land above 4,000 meters elevation where rocks and perpetual snow are found. No agriculture is possible.

6. Land Capability Classification

The system of land capability classification of the United States Soil Conservation Service, as simplified for use in Latin America,7/ is utilized.

Class I, II, III, and IV are used to designate tillable land.
Class I land has few or minor limitations for all adapted crops.
Class II may have more severe but correctable limitations.
Class III has severe limitations.
Class IV has extremely severe limitations but can be cultivated at least one year in four with specially selected crops.
Classes V, VI, and VII include agricultural land not tillable.
Class V can be used for pasture with few if any limitations.
Class VI has severe limitations for pasture but may be used for forest without limitations.
Class VII should be used for forest.
Class VIII includes land of no agricultural value.

Class I

Pichilingue Association is designated Class I since all adapted perennial and annual crops can be grown with few limitations. These are deep well-drained alluvial loam soils with excellent physical conditions. A rainfall deficiency occurs in the southern limits of this Association and would probably reduce these to Class II lands.

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7. Steele, J. G. The Measure of Our Land, Soil Conservation Service, U.S. Department of Agriculture, 1951.

Certain portions of the Naranjito Association have few limitations and these may also be included as Class I.

Class II

The Naranjito Association is included in Class II, since it may be subject to flooding. Irrigation and drainage are required for most all of these lands.

Class III

Daule Association is included in Class III, although an irrigation classification would be preferable. The Daule soils are flat areas at low elevation which are irrigable. Excellent crops of rice can be grown during the dry season but during the wet season they are under water for several months. Drainage and flood protection would be expensive.

Portions of the Balzar, Ayora and Chimbo Associations should technically be included in Class III. However, since most of the area of Chimbo Association is suitable for cultivation only with severe limitations. Class IV is the preferred classification. Class VI is also the preferred classification for Ayora and Balzar Associations, since cultivated crops are at best a marginal operations.

Class IV

The Chimbo Association is placed in Class IV because of the high altitude and steep slopes that restrict the choice of crops and the practicability of cultivation.

The Vinces Association was placed in Class IV because of flooding and high water table. These soils are actually potentially as good or better than the Daule Association, which was placed in Class III, but the infeasibility of economic exploitation limits their utility more than it does the Daule Association.

Class V

Certain lands may be suitable for pasture with few limitations, but these have been included in other associations.

Class VI

The Zumbagua Association can be used for pasture most of the year, although much of the land is cultivated. High elevations restrict the growth of almost all plants.

The Balzar and Ayora Associations are very similar. They have been included in Class VI because lack of water and rolling topography make it difficult to cultivate soil of this type. The long dry season and difficulty in supplying irrigation water further restricts their utility.

The Balzar Association is the better of the two and with irrigation much of the area could produce excellent crops.

Class VII

The Oro, Tambo, and Maná Associations have been included in Class VII since their recommended use is for forests. The Oro and Maná Associations are in fact cultivated for the production of subsistence crops as well as coffee and oranges. Most of the coffee of Ecuador is grown on soils with similar characteristics, which fact indicates the possibility of raising tree crops on these low capability soils.

Class VIII

The Riobamba Association which includes rocks and lands of perpetual snow has been placed in Class VIII since they have no utility except possibly for natural storage of water.

7. Summary

The main characteristics of the various soil associations are summarized in Table 4. A comparison of the soil associations indicates the superiority of the Pichilingue and Naranjito Associations and it would be recommended that additional soil surveys be undertaken to determine more accurately the area occupied by these soils.

The Daule and Vinces Associations are hydromorphic soils now largely used for rice, which is well adapted to the soil conditions.

Ayora and Balzar Associations represent rolling hill soils which could be economically exploited under irrigation. Such development will probably be costly and further study of the irrigability of these soils should be made.

The Chimbo Association soil areas are overpopulated in terms of present production levels, although productivity could probably be raised by means of improved soil and crop management techniques.

The other soil associations have the common problem of high erosion danger, and their use for other than forest or pasture should be restricted to tree crops. Terracing would permit annual crop cultivation.

Forest Resources

As in the case of the geologic and soils investigations, forestry evaluations have been based on reviews of existing data, aerial photo interpretation and field checks made within the Guayas Basin area. Unfortunately, available photography did not cover all of the forested area nor was it of a sufficiently large scale to enable evaluations to be more than reconnaissance estimates. The varying quality of base information available thus resulted in a difference in the reliability of forestry data in the Guayas Basin area.

Table 4

CHARACTERISTICS OF SOIL ASSOCIATIONS OF THE GUAYAS BASIN, ECUADOR

Association	Symbol	Altitude Meters	Rainfall mm.	Slope percent	Parent Material	Vegetation and Land Use	Drainage		pH
							Internal	External	
Pichilingue	P	20-650	2000-3000	0-5	Alluvium from basic intrusives and volcanic ash.	Evergreen broadleaf in north, 25%; 75% cultivated, mainly bananas.	Excellent	Excellent	5.8-7.2
Naranjito	N	0-100	1500-2000	0-10	Unconsol. tertiary alluvium with additions from basic intrusives and volcanic ash; coarse to fine sand with high % of feldspar grains.	Almost entirely cultivated --annual and perennial crops. Some patches of deciduous broadleaf.	Excellent	Fair	5.8-70
Daule	D	0-60	500-1500	0-2	Idem, finer textured.	Annual crops, pasture. Some broadleaf scrub and mangrove.	Poor	Poor	5.3-7.5
Vinces	V	0-60	1500-2000	0-2	Idem, finer textured.	Annual crops, some pasture.	Fair	Poor	5.4-75
Chimbo	C	2000-3000		10-60	Leaned volcanics; some cretaceous (undifferentiated).	High mountain forest, annual crops--grain and tubers, pasture.	Excellent	Excellent	5.5-70
Balzar	B	60-1000	1200-3000	10-60	Tertiary sandstone, shale and limestone. Some volcanics.	40% annual crops and pasture. 30% deciduous broadleaf; 30% Evergreen broadleaf.	Poor	Poor	5.1-8.0
Ayora	A	0-100	500-800	0-5	Silstone, shale; some limestone.	Mixed tree and annual crops. Broadleaf scrub and deciduous broadleaf.	Poor	Poor	5.1-8.0
Zumbagua	Z	3000-4000	400-1500	0-80	Volcanics and sedimentary (cretaceous) rocks.	Pasture, annual crops. Some High Mountain forest in north.	Good	Excellent	5.6-6.5
Oro	O	1000-2000	0-700	60 plus	Sandstone, shale, silstone. Locally iron cemented.	1/2 deciduous broadleaf. 1/2 Evergreen broadleaf. Slight amount of annual Ag.	Fair	Excellent	5.0-7.5
Maná	M	200-1000	2000-3000	20-80	Basic volcanics and diabase intrusives.	Shifting cultivation--perennial crops (coffee) and other subsistence. Low mountain forest. Some Evergreen and deciduous broadleaf at lower elevations.	Good	Excellent	5.5-7.0
Tambo	T	1000-3000	2200-3000	80 plus	Basic volcanic ash and diabase intrusives.	Annual agriculture. High Mountain forest and Páramo. Pasture.	Fair	Excellent	5.5-70
Riobamba	R	3000 plus	1500-2500	10 plus	Basic volcanics and intrusives.	Pasture. Snow.	None	Excellent	-

In general, however, the distribution of the respective vegetation types could be distinguished and demarcated. These types are closely related to temperature and precipitation; the amount of rainfall, its annual distribution, local evapotranspiration rates, soil conditions and the topography of the land are chiefly responsible for types of forest which grow in the Basin. Temperature variations associated with changes in elevation are to a lesser degree determinants of vegetation development, except at extreme altitudes. The forest types occurring in the Guayas Basin can be divided into the following categories: (a) Evergreen broadleaf, (b) Deciduous broadleaf, (c) Scrub broadleaf, (d) Low mountain, (e) High mountain, (f) Mangrove, (g) Eucalyptus. Their distribution has been presented on the Land Use and Forest Types Map (Appendix F).

1. Forest Types

Evergreen broadleaf forests

The evergreen broadleaf forest type contains predominantly evergreen broadleaf species mixed with some deciduous broadleaf species and occurs on a highly dissected and gently sloping plateau in the northeastern sector of the Guayas Basin (see map "Land Use and Forest Types in the Guayas Basin" in Appendix F). The type occurs in an area having an annual rainfall of 2,000 mm. or more. Annual rainfall and its pattern of distribution during the year provide sufficient moisture so that most of the trees in this forest type retain their foliage throughout the entire year.

The tallest trees in this forest type reach heights of about 40 meters and are widely scattered. Trees forming the main crown canopy of this forest type grow to heights of about 30 meters (100 ft.). From their appearance on the aerial photographs and from aerial reconnaissance observations, the evergreen broadleaf forests of the Guayas Basin do not appear to have a dense continuous crown canopy. Because of a discontiguous upper crown canopy, a dense tangle understory consisting of small trees, shrubs and herbaceous plants has become established. Although these forests grow on what appear to be high well-drained sites, their open crown canopy characteristic is more typical of tropical forests occurring on low, poorly drained sites.

Most of the trees in the evergreen broadleaf forest type have diameters of less than one meter; however, a few species such as those of the genera *Ficus* have large buttresses or aerial root systems which attain diameters of from two to four meters. According to published reports (see bibliography, Appendix F) timber volumes of the evergreen broadleaf forests in Ecuador vary from 25,000 to 40,000 board feet (125-200 cu. m.)per hectare. For the areas of this forest type located in the Guayas Basin, the lower volume figure of 25,000 board feet per hectare seems more appropriate. The marketability of the numerous species occurring in the evergreen broadleaf forests is very poorly known. A small, lightly sampled area of this type was found to contain 20 percent of first class furniture and constructional timbers and 18 percent of general constructional timbers; remaining timber species were judged to be suitable only for use as crating or boxing materials.

In the Guayas Basin, pambil palm (*Catostigma* spp.) and guaduá (*Guadua angustifolia*), a bamboo, are prominent components of the evergreen broadleaf forests. In some areas pambil palm, which provides no marketable products, constitutes from 25 to 50 percent of the crown canopy cover. Similarly, guaduá, in low depressed areas, constitutes at times about 25 percent of the crown canopy cover. With such a large amount of area occupied by both pambil palm and guaduá, the amount of land available for more valuable species is greatly reduced. The principal timber species growing in this type include moral (Chlorophora tinctoria), jigua (Nectandra sp.), figueroa (Carapa guianensis), cerdo colorado (Ocotea sp.), colorado (Pouteria sp.), cedro (Cedrela fissilis), amarillo de Guayaquil (Centrolobium patinense), caracoli (Anacardium excelsum) and maría (Calophyllum longifolium). Additional timber species include fernán sánchez (Triplaris guayaquilensis), laurel (Cordial alliodora) and balsa (Ochroma lagopus), which are species characteristic of secondary forests growing on abandoned crop land and along roadsides.

Most of the evergreen broadleaf forests in the Guayas Basin remain unexploited since the area where they occur is poorly populated and inaccessible. Near towns and along roads where the land has been cleared bananas and livestock are the chief agricultural products produced. Of all the forest types found in the Guayas Basin the evergreen broadleaf forests probably contain the largest quantities of usable timbers. If land presently in forest should be cleared for agricultural use in the future, proper utilization of all marketable timbers on these lands during the land clearing operations would provide substantial income to the country. Areas in this forest type with steep slopes should be retained in forest. It would also be advisable to set aside a portion of this land to be managed for its timber products.

Deciduous broadleaf forests

A mixture of evergreen and deciduous broadleaf species occurs in the deciduous broadleaf forest type. Where rainfall is more abundant and fairly well distributed during the year, as in the northern and eastern part of the Guayas Basin, evergreen broadleaf species are abundant but drier regions in the south and west contain predominately deciduous broadleaf species. The transition from evergreen to deciduous corresponds roughly with the transition from tropical wet to tropical dry conditions, that is, from surplus to deficit in annual moisture balance. During the dry season, some but not all of the trees in the deciduous broadleaf forest type lose their foliage. The boundary separating evergreen from deciduous broadleaf forests shows a close correlation to the 2,000 mm. average annual isohyet (rainfall) although soils characteristics influencing water availability undoubtedly cause local anomalies. The minimum annual rainfall values for the deciduous broadleaf forest are 1,000 mm. approximately, although discrete boundaries are used in mapping this forest type. The change from deciduous to evergreen is gradual and can be most easily distinguished at the end of the dry season when the contrast in color between those forests containing trees with foliage and those containing predominately trees without foliage is quite striking. This would be the best time of the year to take aerial photography for forest inventory purposes.

Many of the species that occur in evergreen deciduous transition forests are common also to deciduous broadleaf forests. Other species such as guayacán (Tabebuia chrysantha), roble de Guayaquil (Tabebuia pentaphylla), pechiche (Vitex gigantea), bálsamo (Myroxylon balsamum) and palo de vaca (Alseis eggersii) are typical primarily of deciduous broadleaf forests.

Trees in deciduous broadleaf forests are shorter in height and smaller in diameter than those in evergreen broadleaf forests. There are fewer trees per hectare and shrub and herbaceous ground cover tends to be more dense because the crown canopy is fairly open. Timber volumes in this forest type have been estimated at up to 25,000 board feet (125 cu.m.) per hectare. Typical timber volumes on a lightly exploited area of forest of this type measured in 1943 at the Pichilingue Agricultural Station showed an average volume of 14,000 board feet (70 cu.m.) per hectare (see bibliography, Appendix F). A dense forest, representative of about one-third of the area investigated, contained 23,000 board feet (120 cu.m.) per hectare. Majagua (Hibiscus tiliaceus) and moral bobo (Clarisia racemosa) together constituted about 60 percent of the timber volume in this dense forest stand. The remaining area of unexploited forests contained a volume of about 10,000 board feet (50 cu.m.) per hectare. The preceding forests occupied well-drained ridges along streams, borders. On poorly drained lands a low volume open forest occurred in which bamboo thickets were common. The timber volume in this open forest was estimated at about 4,000 board feet (20 cu.m.) per hectare with fernán sánchez one of the principal commercial timber species present in the stand.

The larger remaining areas of deciduous broadleaf forest are located chiefly in the northern parts of the Provinces of Los Ríos and Manabi. Deciduous broadleaf forests in Los Ríos occur southwest of Quevedo and occupy comparatively flat lands. Deciduous broadleaf forests in Manabi occupy drier lands and adjoin the wetter evergreen broadleaf forests located in the northeastern sector of the Guayas Basin. Most of the lands presently covered by deciduous broadleaf forest appear to have suitable climates for agriculture. Much of the agricultural land in the Guayas Basin was at one time covered by deciduous broadleaf forests. Small scattered areas of this forest type still occur within agricultural areas but it is likely that the better timber species in these stands have already been removed. The same situation is probably true on the fringes of the larger remaining areas of deciduous broadleaf forests where agriculture appears to be gradually converting the lands from a forest cover to cropland.

Deciduous broadleaf forests are important for the production of timber products since they are for the most part located in accessible areas. The forest type also contains substantial volumes of secondary forest timber species such as balsa and laurel, which have grown up on abandoned agricultural land or in heavily exploited forests. Large quantities of balsa, in particular, are exploited from the secondary forests located near Quevedo. The logs are then transported into Quevedo where rafts are constructed from them and the rafts floated down-river to the sawmills near Guayaquil. Laurel, a secondary forest timber species, is fairly abundant and is widely used in furniture, for panelling and interior trim of houses and for general house construction. Laurel grows to a diameter of up to one meter but most trees in accessible areas have diameters of less than 35 centimeters.

For the area that it occupies, the deciduous broadleaf forest supplies substantial quantities of timber; an attempt should therefore be made to improve the composition of these forests. A few teak (Tectona grandis) plantations have already been established in lowland areas of the Guayas Basin and a teak nursery is nearing completion. It is suggested, however, that the major reforestation effort be based upon native species such as balsa, cedro and laurel. The timber qualities and growing characteristics of the native timbers are better known to both local foresters and the sawmill operators.

Cacao and coffee plantations are often shaded by large trees of such species as palo prieto (Erythrina glauca), marañón (Anacardium occidentale), samán (Samanea saman), matapalo and higuerón (Ficus spp.). None of these species is especially valued for its timber and although poorer quality boxing and crating materials can be obtained from them, their felling would probably damage the understory tree crop.

Scrub broadleaf forests

Scrub broadleaf forests are those in which the crowns of the trees seldom touch to form a closed canopy. Both evergreen and deciduous broadleaf species occur in this forest type. In Ecuador, the scrub broadleaf forests occupy the drier sites (less than 1,000 mm. of rainfall per annum) to the west and south of the deciduous broadleaf forests. On the basis of topography and species composition scrub broadleaf forests can be divided into two associations: a flood plain scrub forest and an upland scrub forest, roughly coinciding with, respectively, the area occupied by the Very Dry Tropical Forest and Dry Subtropical Forest plant formation, depicted on the Ecologic Map of Ecuador referred to previously.

Flood plain scrub broadleaf forests occupy flat alluvial land that is frequently inundated for a period of time during the rainy season. Evergreen broadleaf species of the Leguminosae family are abundant in this association. The trees are typically short, small in diameter and have crooked boles and wide flat crowns. Some of the species growing in this forest contain hard durable woods used for such purposes as crossties and posts. Algarrobo (Prosopis inermis), seca (Geoffroea spinosa), cascol (Libidibia corymbosa) and niguito (Muntingia calabura) are a few of the more important timber species occurring in this forest type. Most of the land in the region occupied by the flood plain scrub broadleaf forests is used for agricultural crops, particularly rice, and for grazing, and no large areas remain under forests of this type.

The upland scrub broadleaf forest association is an evergreen and deciduous broadleaf forest which occupies well drained upland sites. Ceibo (Ceiba trichistandra), beldaco (Bombax sp.) and bototillo (Cochlospermum vitifolium) are the principal species represented in the type. All of the preceding species have soft unusable woods, with the exception of ceibo, which provides a nonwood product, kapok, obtained from the seed pod of the tree. Guayacan, a hard durable timber which finishes to a high polish and is especially valuable for use as a turning stock and for crossties, and cascol, are presently the two principal species of value in this forest association.

Accessible areas of the upland scrub broadleaf forest are heavily utilized for grazing and have had much of their useable timbers already removed. Regeneration in this forest association is difficult due to the dry climatic conditions compounded by the abuses of over-grazing. Unexploited and presently inaccessible upland scrub broadleaf forests cover an extensive area of the southern part of the Cordillera de Colonche. Because of its proximity to Guayaquil it seems likely that this area of forest could be rather easily exploited for valuable species such as guayacan.

Low mountain forests

The Western Cordillera of the Andes Mountains abruptly joins the lowlands of the Litoral at elevations ranging from 300 to 500 meters. The subtropical forests, mapped as low mountain forests grow on lower mountain slopes up to elevations of about 2,000 meters where rain in excess of 2,000 mm. (80 ins.) and lower temperatures create very wet conditions. Species of the Lauraceae family become more numerous in this forest type but otherwise the species composition is very similar to that of the evergreen broadleaf forests. Trees in the low mountain forests are predominately evergreen broadleaf but they are shorter in height and smaller in diameter than those in either the evergreen broadleaf or deciduous broadleaf forest types. Timber volumes in unexploited low mountain forest seldom exceed 20,000 board feet (115 cu.m.) per hectare. Near roads and rivers much of the forests of this type have been cleared for agriculture and later to forest. Secondary forests and shifting cultivation are abundant in this forest type, reflecting the rapid loss in fertility through leaching which follows the deforestation of these soils, despite their inherently high fertility.

Oranges, bananas, cascarilla (Cinchona sp.), coffee, cacao and some corn and sugar cane are the chief crops grown on lands cleared of low mountain forest. Much of the lands presently being cultivated for these crops are located on slopes having grades of 50 percent or more, and are rotated between forest and agriculture in a typical shifting cultivation pattern. Where this practice creates erosion danger, shifting cultivation on these steep slopes should be curtailed and the forest cover maintained. These soils are described as having excellent internal and external drainage, however, and a controlled sequence of agriculture and forest fallow might be acceptable.

High mountain forests

High mountain forests begin at an elevation of about 2,000 meters and extend up to the páramos. Where it joins the páramos, trees in the high mountain forests are reduced in stature to the low shrubs. High mountain forests are almost perpetually in clouds and the term cloud forests is sometimes applied to them. Trees in this forest type are short, diameters are generally under 50 centimeters and volumes per hectare are low. Evergreen broadleaf species are predominant in the high mountain forests but a conifer, sisin (Podocarpus sp.) is present in small quantities, particularly in the south. Sisin is a good constructional timber and is also used for cheaper furniture. Valuable broadleaf species in the type include cedro de la Sierra (Cedrela rosei), nogal (Juglans neotropics) which is a variety of walnut, and arrayán (Eugenia sp.).

The lands occupied by the high mountain forests should be retained in forest, particularly in the altitudinal belt above the low mountain where orographic rainfall is between 2,000 mm. (80 ins.) and 1,000 mm. (160 ins.), and erosion danger is high. Generally, soils of the high mountain forests are lower in fertility than those in the low mountain forest, consequently land clearing is less prevalent in this forest type. Probably much of the inter-Andean valley region was once covered by forests of this general type but through years of clearing and cultivation and heavy wood exploitation the high mountain forests located in this area have deteriorated to low shrub-type forests. Substantial areas of unexploited high mountain forest remain in the northern part of the Guayas Basin where road penetration is less.

Mangrove forests

In the Guayas Basin mangrove forest type occupies saline silt soils in the Río Guayas estuary but scattered clumps of mangrove or individual mangrove trees are also found for short distances up the Babahoyo and Daule rivers. The mangrove forest is practically a pure forest type composed almost entirely of mangle colorado (*Rhizophora mangle*). Mangrove forests near Guayaquil are dense but contain mostly short, small diameter trees and the forests are continually cut for fuelwood. The species has a hard durable wood which makes it useful for heavy constructional purposes, crossties and for poles. Mangrove bark also contains a tannin product.

Probably the best use which can be made of the mangrove forests in the Guayas Basin is that for which they are currently being used, i.e., fuelwood. Mangle colorado reproduces itself easily and requires little management for continuous wood production.

Eucalyptus forests

Forests of value in the inter-Andean valleys and basins consist almost entirely of planted groves of eucalyptus (*Eucalyptus globulus*). Usually the plantations are established in valleys or basins near towns. Where sufficient moisture and temperatures are suitable, eucalyptus plantations have been successfully established along hillsides, but in the arid southern Andean valleys eucalyptus grow only in the irrigated valleys. The mountain slopes, though excessively steep, are planted in grain and other field crops.

In the area of the Guayas Basin no substantial areas of eucalyptus occur. Fence rows of eucalyptus and individual trees are common but no sizeable groves or plantations have been established. Competition between various land uses in the inter-Andean valleys is acute and it is likely that in this area use of the land for wood production will always be subordinate to its use for agriculture. There is a great need for wood products and fuelwood in this sector of the country but probably most of this demand will have to be met by transporting the wood from existing lowland forests.

2. Lumber Production

Guayaquil is the center of the sawmill industry for a large area of the Guayas Basin. P. F. Berthon 8/ in his study of sawmills in Guayaquil and San Lorenzo estimated that the mills of Guayaquil received their supply of logs from as far north as Quevedo and as far south as the Peruvian border. The city is still the center of balsa wood production and likely to remain so, but mills

8. Berthon, P. F. *Informe al Gobierno de Ecuador sobre el Desarrollo de las Industrias Forestales de las Regiones de Guayaquil y San Lorenzo*, Rome 1959, 55 p. (FAO Expanded Technical Assistance Bulletin No. 1125).

processing logs other than balsa are plagued by shortages. In regard to log diameters, Berthon found that the majority of logs going through the mills were small. He estimated their average diameter at 42 centimeters and log diameter percentages as follows:

Log diameters in cms.	Percent
65 or larger	10
50-65	20
35-50	50
25-35	20

Logs of such small diameters, as the majority of the above, are too small for efficient milling operations. The large quantity of small logs processed by mills may be attributed to over-exploitation of existing forests around Guayaquil as well as the lack of heavy equipment to remove larger sized logs from the woods after they have been cut.

Berthon further stated in his study that about 70 percent of the logs being received by the mills were generally of low value timber species. His estimate of the price paid for logs of various species by the mills is shown in the following table.

Table 5

Logs, Squared Timbers, and Lumber Prices in U.S. Dollars per Cubic Meter for Sawmills in Guayaquil

	Type of product		
Species	Logs	Squared timbers	Lumber
Fernán sánchez	4.40	7.30	30
Marañón	4.40	7.30	30
Laurel	5.80	10.00	42
Colorado	5.80	10.00	42
Figueroa	7.30	13.50	45
Roble	8.00	16.00	53
Amarillo	11.75	27.50	70
Bálsamo	14.70	35.00	98

The percentage of timber species by volume, received at the mills, is as follows: Common woods for crating and boxing, 45 percent; fernán sánchez and marañón, 25 percent; laurel, colorado and figueroa, 15 percent; roble, amarillo and bálsamo, 5 percent; and mangle, 10 percent.

Practically all of the sawmills in Guayaquil are located on rivers and receive the majority of their logs by rafting. During the dry season balsa rafts floated downriver from Quevedo, are able to keep the balsa mills supplied with raw materials. Logs of other timber species are generally not transported by river during the dry period and the mills must rely primarily on logs obtained by water from coastal areas and transported by truck.

With the exception of large balsa mills, the future of the sawmill industry of Guayaquil looks bleak. It seems most likely that in the future the center of Ecuador's sawmill industry will shift north where an adequate timber supply is available.

In the Guayas Basin, forests capable of sustaining a modern wood processing industry with an adequate supply of timber exist only in the north, chiefly in the Provinces of Pichincha and Manabí. When the new road from Quito to Santo Domingo de los Colorados is completed it will open up new markets for timber from the virtually unexploited forests to the west of this community. If the forests in this area are to be managed for continuous wood production the sawmill industry in and around Santo Domingo de los Colorados should be modernized so that it can produce both more lumber and of better quality. Once reliable information is obtained as to the composition and timber volumes existing in the forests a better decision can be made concerning additional investment for the sawmill industry. In addition to larger saws to handle bigger logs, and band saws to reduce mill waste, the sawmill industry needs to improve its dimensional accuracy in sawing. For exploiting the forests in this area, if they are eventually to be clear cut and converted to agricultural use, it is recommended that a portable sawmill and heavy logging equipment be purchased. The cost of such an investment would total about US$100,000--half for the sawmill equipment and half for the purchase of tractors and other equipment for carrying out the logging operations.

Logging of timber in Ecuador is accomplished by a variety of persons: land owners, paid contractors and by individuals who go into private and state owned lands and either legally or clandestinely remove timber. The regulation of logging practices is needed.

Most of the logging methods currently used in Ecuador are very primitive. Hand labor rather than machinery is used and the larger heavier logs are often left in the forest because they are too difficult to drag or carry to roads or rivers. Tractors large enough to push skid roads into unexploited forest areas and to skid logs to central concentration points are needed badly in order to maintain an adequate supply of logs for the sawmills.

3. Fuelwood and Charcoal Production

In the mountain forests located on the eastern edge of the Guayas Basin and in the mangrove forests south of Guayaquil, charcoal and fuelwood are produced in substantial quantities. Charcoal is produced by stacking the wood, covering it with dirt and then setting fire to the stack. Such a process is very wasteful and results in a low quality product. Small, inexpensive ovens for producing charcoal are available and plans [9] for them are obtainable. The ovens could be produced locally in Ecuador for an estimated cost of US$15.00 each. Their operation is simple, resembling very much the techniques currently used in the dirt kilns, however they are are much more efficient.

9. A Portable Charcoal Kiln, published by the Connecticut Experiment Station, Bulletin 448.

4. Reforestation and Nursery Production

A major program advocated by the Dirección de Bosques of the Ministerio de Fomento is reforestation. It is anticipated that reforestation will be carried out on poor quality agricultural and abandoned lands of the Sierra and the Litoral. To achieve the reforestation goals advocated by the Dirección de Bosques will require accelerated seedling production.

The present system of nurseries in Ecuador consists of small, widely scattered parcels of land devoted to the production of various species of seedlings. Technical supervision of the nurseries is lacking because of the scarcity of trained personnel. Production and distribution techniques are outmoded and storage facilities for seedlings before they are distributed are particularly poor. The services of an expert in nursery operations to assist the local technicians in improving their production, storage and distribution techniques is needed urgently.

It seems advisable, considering the lack of capable technicians, that seedling production be concentrated in a few large nurseries rather than many small ones. With more adequate supervision and the use of enough water and fertilizer, larger quantities of healthier seedling could be produced.

5. Conclusions

Forest resources in the Guayas area are located chiefly in the north and around the outside perimeter of the Basin. The major productive forest area totaling 241,000 hectares is located in the region north of Quevedo. South of Quevedo, once productive forests, because of their accessibility, have in most cases been over-exploited for timber products. Forests located on mountain slopes and on dry sites are of a protective nature and although capable of providing some wood products should be managed primarily for watershed protection. The low mountain forest areas of the Andean slopes cover an estimated 206,750 hectares, some of which could be exploited.

An evaluation of the forest resources of the Guayas Basin is needed for the preparation of a management plan to effectively utilize the potential growing capacity of the existing forests. For the immediate future it is recommended that a forest survey be conducted only for the productive evergreen and deciduous broadleaf forests located in Pichincha and Manabí Provinces. The information obtained from such a survey would provide the basic knowledge of timber volumes and species volumes needed to evaluate further investments in the area.

The area around Santo Domingo de los Colorados looks favorable for further investments in wood processing industries. The community is near to an area of lightly exploited or unexploited forest and favorably located to transportation facilities. Tentatively it is felt that an investment of about US$100,000 would be justified. This amount would provide for a sawmill or sawmill modernization and logging equipment with which to fully utilize the timber potential of this area. However, investments in wood processing facilities and logging equipment should await the results of the forest survey.

Reforestation activities are a major function of the Dirección de Bosques. Reforestation plans have been well developed, however, it is doubtful if the existing nurseries have the capacity to supply the large number of seedlings required for the area advocated in the planting program. Seedling production must be increased in the nurseries and an expert in nursery operations is needed to instruct and advise local personnel on methods and techniques to increase seedling output.

The present methods of producing charcoal in Ecuador are slow and wasteful. The introduction of steel charcoal ovens that can be manufactured locally at a reasonable cost is recommended.

Water Resources and Irrigation

The water resources of the Guayas Basin were studied specifically with regard to irrigation by surface streamflow. Present and potential irrigation areas in the Basin were reconnoitered in July and August 1963 by means of field trips and aerial reconnaissance. The existing irrigation projects of Manuel J. Calle and Milagro were evaluated and zones with irrigation potential were located and mapped (see Fig. 9). The section which follows includes the factual results of the study of irrigation possibilities.

1. Hydrology of the Guayas Basin

The hydrographic basin of the Guayas River has a total area of 33,640 square kilometers, making it the largest drainage system on the South American continent emptying waters into the Pacific. The Basin is fed by run-off from the humid western front of the Andean Cordillera at its eastern limits and from the lower elevation Balzar Plateau in the north. Numerous small tributaries channel their run-off into the Babahoyo and Daule River systems which meander over the southern flood plain to pour their waters into the Guayas River just north of Guayaquil. The Guayas River, after which the Basin is named, runs for a relatively short distance in the southern flood plain and empties into the Golfo de Guayaquil. Surface water movements in the Basin are particularly important in discussing future agricultural development, since too much water or lack of it appear to be major problems retarding agricultural progress. The control and management of surface as well as underground water will be key factors in the economic development of the Guayas Basin.

There are no systematic registers of flow volumes of the extensive drainage system that converges to form the Guayas River. As of mid-1963, the National Meteorology and Hydrology Service had installed only four stream gauging stations within the Basin; on the Daule River at La Capilla, on the Macul River at Puente Carretero, on the Quevedo River near Quevedo, and on the Pilálo River in Esperanza. The latter site, placed in operation in July 1962, is the oldest of the gauging stations. Minimum streamflow measurements have been made at La Puntilla on the Cañar River, and on the Chimbo and Chanchán

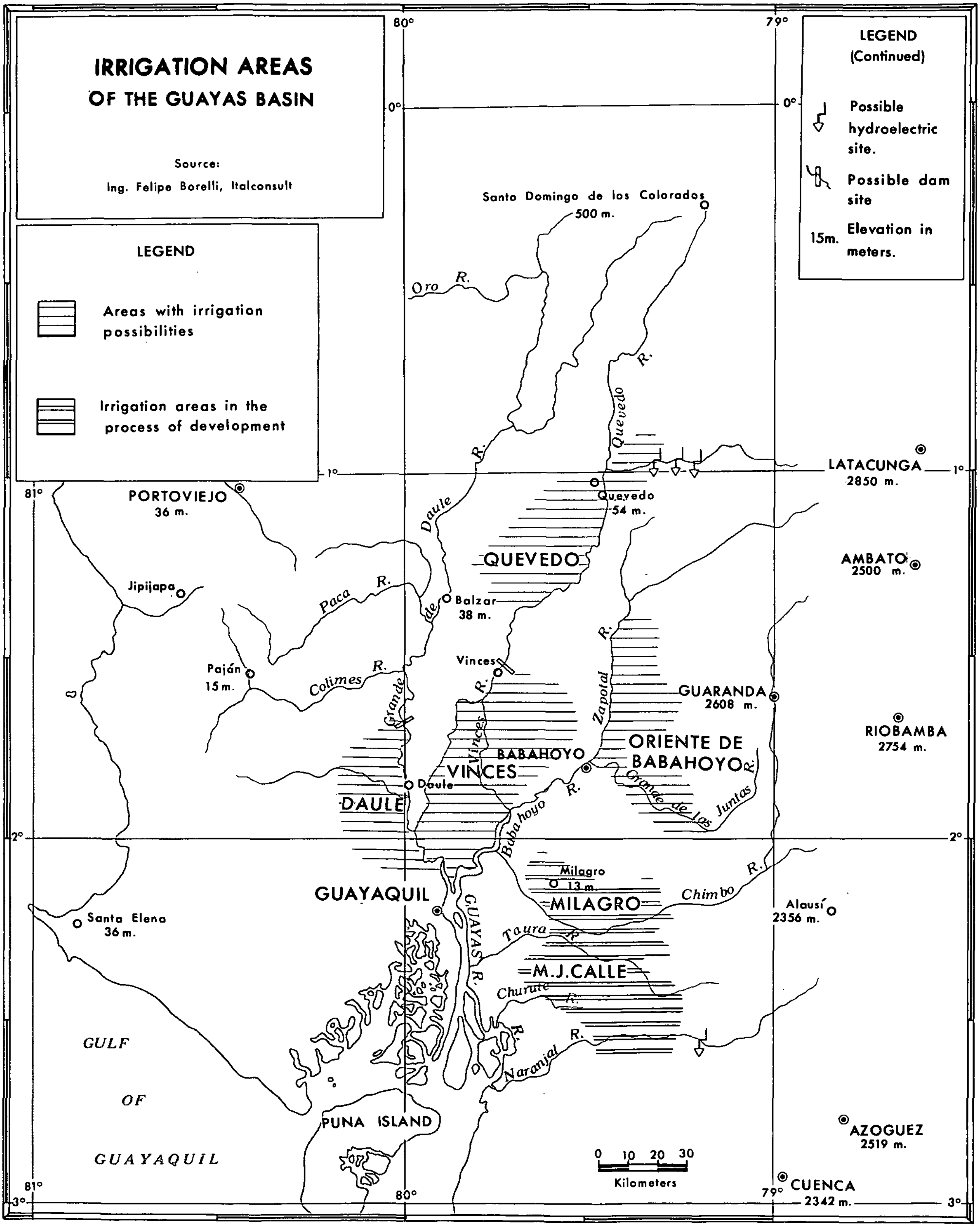
IRRIGATION AREAS
OF THE GUAYAS BASIN
Source:
Ing. Felipe Borelli, Italconsult
LEGEND
Areas with irrigation possibilities
Irrigation areas in the process of development
LEGEND (Continued)
Possible hydroelectric site.
Possible dam site
15m. Elevation in meters.
Santo Domingo de los Colorados 500 m.
Oro R.
Quevedo R.
Daule R.
Quevedo 54 m.
QUEVEDO
LATACUNGA 2850 m.
PORTOVIEJO 36 m.
Jipijapa
Paca R.
Balzar 38 m.
AMBATO 2500 m.
Pajan 15 m.
Colimes R.
Vinces
Vinces R.
Grande de R.
Zapotal R.
GUARANDA 2608 m.
RIOBAMBA 2754 m.
ORIENTE DE BABAHOYO
BABAHOYO
VINCES
Daule
DAULE
Babahoyo R.
Grande de las Juntas R.
Milagro 13 m.
MILAGRO
Chimbo R.
GUAYAQUIL
Alausí 2356 m.
Santa Elena 36 m.
GUAYAS R.
Taura R.
M.J.CALLE
Churute R.
Naranjal R.
GULF OF GUAYAQUIL
PUNA ISLAND
AZOGUEZ 2519 m.
0 10 20 30
Kilometers
CUENCA 2342 m.
80°
79°
81°
0°
1°
2°
3°

Fig. 9

Rivers at the intakes of main irrigation canals. This lack of information, as well as the absence of large scale topographic maps of the Basin, seriously limits any evaluation of surface water resources potential.

The watershed and hydrographic characteristics of the Daule and Babahoyo River systems are quite different. The Daule and its tributaries channel run-off from the humid Balzar Cordillera and plateau area, as well as the sub-humid to semi-arid Colonche and Chongón Cordilleras. It appears that perennial streams flow only in the northwestern part of the watershed, while few of the streams originating in the Colonche and Chongón Cordilleras to the southwest have year-round flow. In this latter region, however, the landscape is predominantly shaped by stream erosion.

The Babahoyo River system drains the eastern half of the Guayas Basin; numerous torrential streams catch the run-off from the orographic rain which falls on the western slopes of the Andean Cordillera from Bucay in the south to Pilaló in the north. It is interesting that the Vinces River, one of the major affluents of the Babahoyo system, is linked to the Daule River system via the Pyla River. It may be that during the rainy season streamflow from the Vinces River is diverted into the Daule River via that stream. In the lower part of the Guayas Plain the terrain is generally flat, and swampy conditions occur during the rainy season.

Although there is insufficient streamflow data to make regional comparisons of the flow volume of these two major tributaries of the Guayas Basin, it is evident that the greatest amount of run-off reaches the Babahoyo River system, and that there is less fluctuation in total streamflow in this system than occurs in the Daule River. Thus, the tributaries of the Babahoyo River offer better possibilities for the diversion of water for irrigation from the standpoint of water availability. Furthermore, the hydrographic characteristics of the Babahoyo system are more homogeneous than those of the Daule system. The numerous tributary streams of the Babahoyo which descend from the Andean front have similar gradients and other watershed characteristics, so that their development for irrigation or hydroelectric purposes would entail similar problems and require similar procedures. For instance, their steep gradients and narrow valleys limit the feasibility of large reservoirs, while small hydroelectric sites are possible. Vegetation throughout the upper watersheds of these tributaries must be managed so as to curtail run-off and erosion. This is especially pertinent in view of the fact that floods during the rainy season are reported to occur in the productive southern portion of the Guayas Plain where the waters of the mountain streams merge to form the Babahoyo River. These floods, which are particularly severe during years of high rainfall, could be catastrophic if the upper watershed were deforested.

Groundwater resources of the Guayas Basin have not been studied. However, geologic information indicates that the sediments of the Guayas Plain possess a good groundwater potential. The coarse sediments which underlie the Andean piedmont are probably fed year-round by sub-surface run-off from the humid Andean slopes, in addition to receiving percolating groundwater during the rainy season. Finer sediments are characteristic of the central and southern portion of the Guayas Plain. Good aquifers could possibly be located particularly along the courses of buried stream beds. The comparative economics of groundwater exploitation versus surface water use for irrigation should be studied. Certainly for some areas of the Guayas Plain with problems of water impoundment or canal construction, it will be more economical to exploit groundwater than to utilize existing surface water.

2. Problems Related to the Development of Water Resources

The development of both surface and sub-surface water resources for irrigation will provide a great stimulus to agricultural intensification. Some potential exists for developing hydroelectric power projects; however, maximum use in industry does not appear to be as immediate a possibility as does the development of irrigation for agriculture. The development of irrigation utilizing surface water has already been undertaken in the southern flood plain. Two projects, the Manuel J. Calle and Milagro, are already in the process of development. Other areas that apparently have good potential for irrigation development have been demarcated, but economic feasibility data required to substantiate the areas tentatively selected are not yet available (see Fig. 9).

An important consideration in assessing irrigation possibilities is the limitation posed by terrain conditions. Low level land characterized by poor drainage is found throughout the southern flood plain which is susceptible to flooding. A high water table in this area causes hydromorphic or marshy conditions, placing considerable limitations on the agricultural use of such land. The southernmost portion of the flood plain has further limitations, since much of the land is affected by saline tidal waters from the Gulf of Guayaquil. Another important consideration affecting irrigation in the Guayas Basin is the minimum flow of the streams during the dry season when irrigation water is needed. In that regard insufficient data are available on streamflow to enable accurate estimates of the water which would be available during the dry season. However, it is evident there is a considerable variation in monthly streamflow, even from the streams that originate in the Andean Cordillera. In addition, estimates of irrigable terrain are not possible without reference to detailed topographic maps, which do not exist for those zones that show the most promise. 10/

There is a greater potential for irrigation and hydroelectric development in the Babahoyo watershed than in that of the Daule River. It has been noted that the Babahoyo system has perennial streams which drain the western slopes of the Andean Cordillera, and that a greater total volume of run-off enters the Babahoyo system than the Daule system. Furthermore, the agricultural soils

10. The demarcation of irrigable zones or those requiring drainage measures, as depicted on Fig. 9, and the representation of swampy areas, as compiled by the Military Geographic Institute on its 1:500,000 topographic map of the area, show certain discrepancies which can be seen on the map entitled "The Composite Evaluation of Natural Resources in the Guayas Basin" (Appendix F) in which both sources have been utilized. These differences serve to illustrate the limitations of cartographic compilation when attempted on a poor cartographic base and point out the need for aerial photographs and detailed topographic maps in order to accurately determine zones with irrigable terrain or in need of drainage measures.

within the Babahoyo watershed have similar fertility levels and management problems; they generally require supplementary irrigation during at least six months of the year. Control of run-off in the watershed as well as erosion of land is closely related to the existing vegetation cover on the steep Andean slopes which receive heavy orographic rainfall. Due to the similarity of physical characteristics, as well as developmental potentials, it would be advisable to view the entire Babahoyo watershed as a unit that should be studied and developed as a secondary or tributary river basin within the major watershed of the Guayas Basin.

The irrigable terrain in the Daule River system watershed is located primarily in the southern flood plain. To the north in the headwaters area of the Daule, precipitation is greater, local relief increases and the land is dissected. In the southern flood plain the principal limitations to irrigation development along the Daule River are terrain and inadequate drainage. The latter problem is more serious along this river than in the lands to the east drained by the Babahoyo. Extensive level land areas and slight stream gradient in the lower Daule almost eliminate the possibility of impounding water for irrigation, and do not permit building an irrigation canal system based on gravity conduction. Furthermore, the areal extent of soils affected by intrusions of tidal waters along the lower Daule has not as yet been determined. These and other problems require investigation, but with a considerable degree of certainty it can be concluded that the cost of developing the lower reaches of the Daule River through irrigation and drainage would be high in comparison to similar projects in the Babahoyo watershed.

3. Evaluation of the Milagro and Manuel J. Calle Irrigation Projects

East of Guayaquil and in the flood plain and piedmont near the Andean front, two irrigation projects are being developed by the Caja Nacional de Riego (CNR), the Ecuadorian agency responsible for irrigation development. They are called the Milagro and the Manuel J. Calle Irrigation Projects.

The Milagro Project

The Milagro Irrigation Project is located near the town of Milagro, about 40 kilometers from Guayaquil (see Fig. 9).11/ The project was initiated by the CNR in 1949, principally at the request of the Valdez sugar plantation and mill. By 1963, about 2,400 hectares had been put under irrigation, half of them part of the Valdez plantation.

Water for this project is diverted from the Chimbo River (whose headwaters are on the Chimborazo Volcano), and the Chanchán River, a major tributary of the Chimbo. The Chimbo River watershed has a total area of approximately 2,200 square kilometers and the Chanchán River watershed covers about 1,500 square kilometers. During the June to December dry season in the Guayas

11. Due to the small scale of available base maps and apparent discrepancies in the portrayal of streams on these, it was not possible to accurately delimit the area of the Milagro project. The area shown on Fig. 9 represents the total area of irrigable terrain.

Basin when irrigation water is needed, streamflow originates from orographic rainfall in the Andean Cordillera and the Chimbo River receives additional water from the melting snowfield and glaciers on Chimborazo Volcano.

At the main canal intakes of the Milagro project, the dry season streamflow of the Chimbo and Chanchán Rivers is 14 cubic meters/sec. and 4 cubic meters/sec., respectively. The CNR has rights to two thirds of the flow of the Chimbo and one half of the flow of the Chanchán, a total of roughly 10 cubic meters/sec. The remainder is claimed by the San Carlos sugar plantation, according to water rights established prior to the inception of this CNR project.

The CNR plans eventually to irrigate 10,000 hectares, however, present plans provide only for the construction of intakes, main canal and primary distribution networks. The construction of secondary canals and distribution networks and drainage canals is the responsibility of the individual water user. In addition to utilizing canals for conducting water, natural streamcourses of intermittent streams, called "esteros," are used. The Milagro River is one of these. Thus, water is diverted from the main intake on the Chimbo River to the irrigated lands downstream and north of the Chimbo by mean of a succession of canals and esteros. The esteros do not normally contain water during the dry months.

The CNR has made studies and undertaken construction at the request of farmers in the Milagro area. Measurements of low water streamflow were begun in 1953, but permanent gauging stations have now been established. Detailed topographic surveys have been made for canal construction and for part of the irrigated lands, but no soils surveys have been made of any part of the area. Plans for internal distribution networks have been prepared for part of irrigated area, but little construction has been carried out.

By August 1963, the following had been constructed: the principal intake on the Chimbo River; a number of primary and secondary canals between esteros; diversion dams on two esteros; and feeder canals to the Valdez sugar plantation, and a number of other properties. The CNR has invested 7 million sucres out of the projected total of 10.5 million needed to terminate the network planned for the 10,000 hectares. Unit area costs of 1,050 sucres/hect. (U.S. $58.33/hect. at 18 sucres/U.S.$1.00) are low for several reasons: they do not include the expense of secondary canal systems for the individual farms or provisions for lining canals; and the water is transported for considerable distances via the natural streamcourses of esteros, which also results in savings.

Irrigation is practiced for six months (mid-June to mid-December), and the principal irrigated crop and largest water user is sugar cane. Farm operators contract the CNR for one liter/sec./hect., i.e., one cubic meter/1,000 hectares. One half of the presently irrigated area, about 1,200 hectares, is part of the Valdez plantation where annual sugar cane is irrigated by means of sprinkler systems. Two inches of water (500 cubic meters/hect.) are applied seven times during the dry season. Other users cultivate cocoa, coffee, and tropical fruits such as pineapple, as well as sugar cane. Irrigation is carried out by flooding. These recipient farmers have not levelled their land nor have they utilized the distribution network schemes planned by the CNR.

In depressions and land areas of poor drainage waterlogging occurs, decreasing the amount of usable land.

On the San Carlos sugar plantation, which has a private system, land is levelled and irrigation by flooding is done 8 to 9 times during the dry season, 2 inches of water being applied each time.

Evaluation. The CNR policy of undertaking construction as requests are made, without reference to an over-all plan, conspires against the rapid development of the area. Although finished works are well-engineered and constructed, these alone are not sufficient to insure adequate and efficient water transport and use. No provisions have been made for lining canals or those portions of esteros used for conducting water. Considerable amounts of water are thus lost through seepage, a loss that may be greater than the savings accrued from substitution for canals. On the Valdez sugar plantation, the application of irrigation water by sprinklers results in considerable water loss by evaporation, especially when the sugar cane is well developed and nearing maturity. On other lands, water use by the flooding method is inefficient since the fields are not graded. Farmers, especially on many of the smaller properties are not acquainted with the principals of irrigation and varying water requirements for different crops. It has also been noted that in some cases excessive amounts of water are being applied to crops such as cacao.

In conclusion, the CNR Milagro project as presently planned will not provide the facilities and services for the most efficient water use in the projected 10,000 hectares area. This is principally because the CNR does not plan to construct distribution networks for fields on individual properties. The present situation indicates that individual farm operators either are not interested or are not able to do this for themselves. Furthermore, seepage losses in the unlined main canal and feeder canal systems and the esteros will substantially reduce the amount of water that could actually be delivered to the farms. If seepage losses in the canal system are not corrected it will probably be impossible to irrigate the projected 10,000 hectares. Calculations for the irrigation apparently were made on the bases of 10 cubic meters/sec. streamflow being available at the main canal intake on the Chimbo River. Based on an allotment rate of one liter/sec./hectare, this volume of streamflow would theoretically be sufficient for the 10,000 hectares, but seepage and evaporation losses would reduce this amount significantly.

The Manuel J. Calle Project

The Manuel J. Calle Irrigation Project is located in the southwesternmost sector of the Guayas Basin between the courses of the Bulubulu and Cañar 12/ Rivers in the vicinity of the town of Manuel J. Calle (see Fig. 9). In 1958, the CNR began the construction of irrigation works which were destined to stimulate the colonization and agricultural development of this area and provide water for an estimated 15,000 hectares. The project area measures roughly 16 kilometers from north to south and 32 kilometers east to west.

12. The Cañar River, which is south of the Bulubulu River and roughly parallel to it, does not appear on Fig. 9. It empties into the southernmost extension of the Guayas River delta via the Naranjal River.

Irrigation water is diverted from the Cañar River, which has a watershed area of approximately 1,100 square kilometers upstream from the main intake. The minimum streamflow at the main canal intake has been measured at 14 cubic meters/sec., although 12 cubic meters/sec. is a more realistic figure. The area has good groundwater potential. A well drilled at La Puntilla revealed a semi-artesian aquifer at 9 meters which maintained a groundwater level at 2 meters below the surface.

The Manuel J. Calle area has recently undergone agricultural settlement following the parcelization of a United Fruit Company farm at Vainillo. Additional land has been cleared of forest and put into agricultural use. Property sizes in the area are relatively large: 200 to 300 hectares. Of the 3,400 hectares estimated to be under cultivation, approximately 1,000 are under irrigation. The principal irrigated crop is bananas; cacao plantations and pastures are also irrigated. Dryland crops include winter rice, pasture and unirrigated bananas, plantains, cacao and coffee. Uncultivated areas west of the project are in virgin forest.

As an aid to planning and construction of the irrigation works the CNR has made topographic maps of part of the area, which have been available since 1961. No soils survey has been made of the region. The irrigation works are planned to provide for the facilities needed to deliver water close to individual properties, but no secondary distribution networks are contemplated. As in the case of the Milagro Project, estero streamcourses will be used for conducting water flow. The CNR plans provide for the construction of the following: a diversion dam on the Cañar River (at 164 m. above sea level); a lateral intake and a concrete lined tunnel, both for 12 cubic meters/sec.; a catchment basin fed by the tunnel; main canals, half of which will be lined; branch canals for 1 cubic meter/sec. (La Puntilla to Cañar) and 7 cubic meters/sec. (Vainillo branch), neither of which are planned to be lined; and a stepped chute to be used for running a small hydroelectric plant. In August 1963, work had been completed on the following: the main intake on the Cañar River, the catchment basin and its tunnel; the stepped chute and its canal; a main canal to the Cochanchay Estero, which runs between the Bulubulu and Cañar River courses and parallel to them; a canal from the Cochancay Estero to the Ruidoso Estero; and a temporary canal from the Cochancay Estero to Vainillo. The excavation of the Vainillo branch canal was partially complete and when finished will replace the temporary canal from Cochanchay Estero to Vainillo.

By 1963, the CNR had invested a total of 3.9 million sucres. Part of these funds had been provided from public bonds purchased by the National Banana Producers Association (Asociación Nacional de Bananeros), an arrangement that has proved somewhat unsatisfactory due to delays in funding arrangements. Consequently the implementation of proposed construction has not proceeded according to schedule. The CNR estimates that an additional 4.3 million sucres will be needed to complete the project.

The 1,000 hectares area that is already under irrigation is located near Vainillo. A water volume of one to one-and-a-half cubic meters/sec. is used to irrigate this sector, distribution and delivery being supervised by the CNR. Individual water users have constructed provisional canals for diverting the water to their properties. None of these are lined or otherwise conditioned to prevent seepage loss. No observations of consumptive use for the different crops grown in the area have been made. Information on crop requirements for this area could vary significantly from those at the Milagro Project because the Manuel J. Calle region is far enough south to experience the climatic effects of the cold offshore ocean currents during the dry season. Ground fogs, known as "garua," occur at night and do not dissipate until 11:00 a.m. These fogs are undoubtedly an important source of atmospheric moisture, which may reduce dry season irrigation requirements particularly for crops such as bananas, cacao and coffee.

Evaluation. According to an ITALCONSULT report,13/ the CNR allocates 1 liter/sec./hectare to water users on other irrigation projects. At this rate the streamflow of 12 cubic meters/sec. at the main intake of this project is not sufficient to irrigate the projected 15,000 hectares. However, the irrigation requirements of tree drops, the preferred crop of the area, do not appear to be as great as for sugar cane. Also the occurrence of dry season ground fogs, which carry moisture that condenses on the foliage, helps to satisfy water requirements. Thus, available stream flow may in actuality be sufficient to irrigate 15,000 hectares, providing crops with high water requirements are not cultivated.

Present plans call for only partial lining of canals. This will result in substantial water loss through seepage. Also, no adequate secondary distribution network is presently contemplated, and the lack of such plans will not lead to the maximum use of water resources. No cost estimates of these important facets in the irrigation network are included in the additional 4.3 million sucres which the CNR claims will be needed to complete the construction of planned facilities. The costs of lining the main canals, which must some day be undertaken, and the construction of secondary distribution networks may be three to four times as great as the estimated total of 8.2 million sucres that are to be spent on the project.

With regard to future financing of the project, arrangements should be made to permit project completion in accordance with a predetermined time schedule, and costs for canal lining as well as construction of the secondary distribution network should be included in the over-all project cost. This will result in financial savings in the long run. If sufficient funds are not available from sporadic contributors from the private sector a feasibility study of the proposed project should be undertaken and an attempt be made to get international financing.

General conclusions

Experiences in the irrigation of the Manuel J. Calle and Milagro projects indicate that the construction of diversion works and main canals does not guarantee efficient water use for agriculture. Efficient water use can be achieved only if the water is applied in correct amounts and at the proper time. This necessitates the construction of internal distribution networks on individual farms, drainage canals, grading of land, and other engineering works. The farm operators of most small- or medium-size holdings do not appear to possess the means or knowledge to carry out such land improvement

13. Ferrari, B. V., and Metteo, Alfredo. Análisis del Distrito de Riego de Manuel J. Calle (manuscript).

activities. The success of present and future irrigation projects thus depends largely on the provision of technical and financial assistance to these individuals.

Neither the Manuel J. Calle nor Milagro projects were carried out with reference to an over-all plan based upon prior studies of the soils and water resources of the area to be irrigated. This was due partly to the fact that although the CNR did not initiate the projects, but acted on requests of farm owners, it now finds itself responsible for the irrigation development. Fortunately, both the soils and water resources of both projects provide a good base for irrigation agriculture. The location of future irrigation projects may not be so fortuitous, however, if prior investigations are not undertaken. If a sound regional development plan is to be established, every effort should be made to obtain detailed information on the soils as well as ground and surface water resources of the entire lower Guayas plain which could be affected by irrigation or drainage projects.

Summary

1. Climate

The greater part of the Guayas Basin is characterized by a tropical climate, with temperatures averaging 22° -25°C. Rises in elevation, particularly in the eastern portion of the Basin, cause mean temperatures to drop and Subtropical and Montane conditions occur on the lower Andean slopes. A general high percent of cloud cover and the presence of the cold Humboldt Current offshore result in average annual temperatures a few degrees lower than normal for equatorial latitudes. Rainfall varies tremendously within the Basin. Semi-arid conditions are found in the southern extremities while tropical wet conditions occur in the north. The rainfall is seasonally unreliable and has an uneven distribution. It also varies greatly in amount, even at the same latitude. Trending from the west to the east, rainfall increases from 200 mm. (8 ins.) per year to as high as 3,000 mm. (120 ins.) in a year. A prolonged six to seven-month dry season occurs over about half of the lowland Plain, and only toward the foothills of the Andean Cordillera does annual rainfall exceed rates of evapotranspiration.

2. Geomorphology and Geology

The Guayas Basin is comprised of the low level alluvial Plain of the Guayas River system flanked by the slightly elevated, dissected plateaus and hill country of the Balzar, Colonche and Chongón ranges to the west and northwest. On the east it is bordered by the extremely steep slopes and high mountains of the Andean Cordillera. The latter consists principally of uplifted sedimentary rocks and igneous intrusives which form a pedestal on which volcanic cones and old intrusive remnants attain heights exceeding 6,000 m. The Guayas Plain slopes toward the south from 600 m. in its dissected northern portion to a flat, near sea level flood plain near Guayaquil. It consists of unconsolidated sediments, including stream deposited volcanic materials that have been carried out over the Plain by numerous tributary streams. These tributaries converge to form the meandering Guayas River to the south. The low ranges to the west and northwest are composed of sandstones, siltstones, shale and limestone, which in places are deeply incised by stream action; resistant sandstone facies form steep scarps.

Some mineralized areas are found along the Andean front. Local deposits of copper, lead, zinc, gold, silver, sulfur, barite and molybdenum minerals have been located, some of which are being exploited on a small scale. Limestone is quarried near Guayaquil for cement manufacture, there is growing activity in the quarrying of some types of igneous rocks for construction purposes, and volcanic cinder and pumice have been used for the manufacture of crude cement blocks. Sand and gravel deposits have been quarried for road construction and local clays are widely used for making adobes and fired brick; minor sources of kaolin are known to exist.

No gas, oil or coal deposits have been discovered in the Basin, nor do exploration results point to this likelihood. The Eocene formation from which most of Ecuador's petroleum is derived is found just to the southwest of the Basin.

3. Soils

The soils of the Guayas Plain range from fertile, well-drained, alluvial soils in the north to hydromorphic soils subject to local and seasonal flooding in the south. Zonal latosols predominate in the northwestern plateau area of the Balzar Cordillera and cover much of the sedimentary stratas of the Colonche and Chongón ranges. Near the foot of the coastal ranges, gray calcic soils have developed, while red and brown clays are formed in the semi-arid hill and plateau areas to the southwest. Immature soils characterize much of the steep, humid slopes of the Andean foothills. These soils derive for the most part from basic igneous rocks or from recent volcanics. The high inter-Andean valleys have soils derived largely from recent volcanics.

In terms of drainage and fertility, the best agricultural soils occupy the upper reaches of the Vinces (Palenque) River and the piedmont areas at the foot of the Andean Cordillera, where the land is well drained and basic volcanic material has developed to provide fertile alluviums.

4. Vegetation

The reconnaissance evaluation of the forest resources of the Guayas basin indicates that the northern part of the Río Grande de Daule watershed, covered by a broadleaf evergreen forest, has the highest timber potential of the Basin. The evergreen broadleaf forests are found on the hills and dissected plains of the watershed and are relatively accessible to the Guayaquil and local markets. A total of 193.875 hectares of this type of forest are included in the Basin. Although the forest includes considerable areas where non-commercial species like the pambil palm and guadua predominate, the evergreen broadleaf forest in general has a high potential and timber volume has been estimated at 25,000 board feet/hectare (125 cubic meters).

The deciduous broadleaf forest predominates toward the west of the evergreen forest area, due largely to the more pronounced dry season. It is found in tropical areas where precipitation is less than 2,000 mm. and attains subtropical characteristics at elevations above 1,000 m. in the dissected plateau west of the Río Grande de Daule. A total of more than 250,000 hectares of this type of forest has been demarcated in the Basin. Approximately 40 percent of these forests have been heavily exploited. Timber volumes of the area range between 10,000 and 20,000 board feet/hectare (50 to 100 cubic meters), including balsa, laurel (Cordia Alliodora) and other commercially valuable timber.

To the southwest of this area the presence of a dry scrub broadleaf forest reflects a diminishing annual rainfall. Here the hill slopes of the Colonche and Chongón ranges and many of the valleys have been deforested, and what woods are available are used primarily for firewood. Some kapok is also collected.

In the eastern portion of the Guayas Basin, however, precipitation is greater and low mountain forests cover the slopes of the Andean Cordillera. This large area of 206,750 hectares apparently includes few species suitable for present day exploitation. Timber volumes of up to 20,000 board feet/hectare are found, but these are primarily isolated cases in relatively inaccessible areas. In some areas the forest is slowly being cleared for coffee plantation and subsistence farming, but in general the low quality virgin forest remains untouched.

In the extreme south, around the estuary of the Río Guayas, mangrove forests are found. There are presently being exploited for local charcoal manufacture although the reduction techniques are reported to be inefficient.

5. Water Resources and Irrigation

The principal tributaries of the Guayas River are the Daule, Vinces and Babahoyo Rivers, whose headwaters arise in heavy rainfall areas in the dissected uplands of the north and northeastern limits of the Guayas Basin and along the Andean front. The streams meander over the southern flood plain to converge with the Guayas River near Guayaquil.

Steep, fast streams channel run-off from the humid Andean Cordillera front into the Vinces and Babahoyo, while the Daule River drains the humid plateau areas of the northern Balzar Cordillera, as well as the drier Colonche and Chongón ranges. Since there is a complete lack of stream flow data (only four stations have been installed, the oldest being in operation for less than a year), no accurate interpretations of water flow and volume can be made. It appears that the largest volume of superficial run-off reaches the streams draining the Andean Cordillera front, explaining the importance of the Babahoyo as a principal affluent. The steep gradients of the tributaries of the Babahoyo River in the Andean Cordillera are reduced radically as they flow out onto the flat flood plain of the Guayas valley. This accounts in part for the propensity of this area to flood during the rainy season, when orographic precipitation is maximum.

Irrigation development has been initiated in the southeast flood plain, where two projects derive their water from the Chimbo and the Cañar Rivers which flow to the Guayas River delta, both tributaries of the Babahoyo. The Chimbo supplies irrigation water via a private network of canals to the San Carlos sugar plantation. Other properties will also receive water from the Río Chimbo by means of facilities constructed by the National Irrigation Bureau (NIB) which are planned to irrigate 10,000 hectares, known as the Milagro Project. Although the engineered works are well constructed, in general, little planning preceded development of the Milagro Project. Secondary distribution networks are left to private initiative and are reported as deficient. In the Cañar River area the construction of the irrigation network is being undertaken by the National Irrigation Bureau (the Manuel J. Calle Project). Intakes and main canals were planned, but NIB financing of the necessary secondary distribution system was not contemplated. This must be undertaken by the property owners. The construction was begun in 1958, the project reportedly is lacking funds for completion. Both irrigation areas under development apparently were not based on over-all irrigation evaluations of the Guayas Basin or originally considered as a part of the integrated development plans of the region.

CHAPTER III

Analysis of Natural Resource Potentials

The environmental factors characterizing the Guayas Basin exhibit fairly straightforward cause-and-effect relationships, but the geographic diversity of environmental conditions is exceedingly great, even at the reconnaissance level of the present study. This of course results in considerable variation in resource potentials from place to place, which are to some extent reflected in existing land use patterns and population distribution. The local variations in resource potential, however, when taken together and viewed from the standpoint of the development of the entire river basin, constitute complementary elements which offer good possibilities for integrated development.

A number of general characteristics of the Basin are outstandingly unique and at the same time enhance the potential value of its physical resources. It straddles a climatic transition zone between regional extremes of humidity in the north, along the west coast of Colombia, and aridity in the south, from the Sechura Desert to northern Chile on the Pacific littoral. Over most of the Basin, however, intermediate humidity conditions are found, which for the most part are favorable to plant development. It is the largest river basin on the Pacific coast of South America and it is the only sizeble river basin in the humid tropics of Latin America with large areas of fertile alluvial soils derived from recent volcanic materials, over terrain with generally gentle relief. It has deep water port facilities which link it to international markets and stimulate the production of export crops. Finally, its tropical products have good access to national markets.

Analysis of Environmental Factors

The analysis of environmental factors within the Guayas Basin reveals a tremendous diversity of physical conditions. Climatically it is as diverse as any basin of comparable size in the Western Hemisphere. Climatic differences reflect not only the broad regional trends mentioned above but also local differences due to physiography. While most of the basin has tropical or subtropical temperatures with fairly constant and predictable changes, the rainfall pattern is exceedingly complex. Seasonal rainfall variations are extreme, and total annual precipitation from year to year varies radically, due largely to shifting ocean currents.

Climatic variations are reflected in great seasonal variations in streamflow within the Guayas Basin. While the flow in all streams is diminished during the dry season, the streams in the Daule watershed within the Guayas Basin show particularly radical decreases in run-off. The Babohoyo sub-basin, on the other hand, records a more regular year-round flow, since much of its run-off originates from the perennially humid lower Andean slopes. Run-off is increased in all watersheds during the rainy season, when an average of over 300 mm, per month of precipitation falls over much of the Basin. This results in accelerated erosion and landslides on steep terrain and extensive flooding in the southern half of the Guayas River flood plain. The intermittent streams in the western half of the Basin also cause occasional floods, but these are of a more local nature and their ocurrence is less predictable because of the erratic rainfall patterns affecting this sector. Unfortunately, the almost complete lack of streamflow data does not permit accurate interpretations of the streamflow characteristics of the various sub-basins of the Guayas watershed, but it is evident that the variations between sub-basins are very large.

The soils of the Guayas Basin also present a fairly complex pattern due not only to the great variations in climate and physiography, but also to the variety of parent materials. The geologic past has provided Ecuador with a series of low coastal ranges behind which alluvial sediments from the western slopes of the Andes have been deposited to form a broad river plain of relatively gentle relief. A large portion of these sediments, derived from volcanic and igneous rocks, has received additions of volcanic ash from time to time during recent geologic history. The result has been the development of extremely fertile soils. Generally the soils of the Basin are genetically young and thus reflect the nature of their parent materials. Marked local differences are encountered where exceptionally good quality soils may be found adjacent to soils of very poor quality. Local drainage characteristics, particularly in the flat southern flood plain, account for some very heterogeneous soil patterns, with hydromorphic soils in close proximity to well-drained alluvials. In the northern part of the Basin, as well as along the Andean foothills, the mineral constituents of the parent rock or alluvium over which soils have developed are important determinants of inherent soil fertility. Some soils, particularly the Pichilingue Association, are exceptionally fertile, due largely to the volcanic origin of the parent materials. Other soils in close proximity having more acidic parent materials tend to be latosolic and low in fertility.

The climax vegetation found in the Guayas Basin also reflects the great diversity of climatic, hydrologic and edaphic conditions. In the forested areas of the northern part of the Basin, deciduous species are commonly found on well-drained sites, while edaphic associations, with palms predominating, occur over relatively large areas of poorly drained soils, both in decidous and evergreen forests. Poorly drained sites in deforested areas have been converted to pastures or remain marshy. Where seasonal moisture deficits do not occur, as in the northeastern part of the Balzar Plateau and along the foot of the steep Andean front, evergreen broadleaf forests have established themselves. Over the southern flood plain and adjacent western hills and valleys, sub-humid to semi-arid conditions have restricted vegetation growth to low deciduous and xerophytic scrub forests, although above 1,000 meters of elevation low temperatures increase rainfall efficiency, permitting the development of more verdant subtropical vegetation.

The environmental relationships discussed above show geographic patterns which correspond closely to the arrangement of the tributary rivers and their component watersheds in the Guayas Basin. This is particularly true in respect to sedimentation processes and drainage conditions, which vary considerably for different river systems and which are particularly important to plant development. They result in differences in local soil characteristics such as natural fertility, root penetration, aeration and drainage, which are primary considerations in assessing agricultural capabilities and irrigation possibilities. On the other hand, local climatic and vegetation characteristics of the upper watersheds make their influences felt in the lower flood plain. The phenomenon of regional flooding which occurs generally south of Vinces must be explained in terms of these characteristics at the headwaters of the numerous small rivers that converge on the lower Guayas plain.

The specific and interrelated environmental conditions encountered in the Guayas Basin can be viewed in terms of their functioning relationships to the entire Guayas River system. This point of view is particularly convenient and sound for approaching certain development problems. Agricultural development will be concerned with specific projects in relatively small areas, such as land colonization, as well as regional problems affecting fairly large areas, such as irrigation and drainage works. These could well be oriented to the local as well as regional hydrographic characteristics of the Guayas River and its many tributaries and small watersheds.

Analysis of Population Distribution

The map, "Population Distribution in the Guayas Basin" (Appendix F),1/ which shows some interesting correlations with environmental factors affecting agriculture, at the same time reveals some striking anomalies. In the easternmost portion of the watershed, which includes several inter-Andean valleys, relatively dense population concentrations are found in areas which have been inhabited since the time of the Inca or pre-Inca civilizations. At lower elevations of the Guayas Basin, in arid tropical and subtropical climates, almost comparable densities are found, particularly on the steep and dissected hill slopes of the Chongón and Colonche Cordilleras. In all probability the sparse hillside vegetation cover of broadleaf scrub forest permits easier settlement than in the more densely forested portions of the Basin or than in those areas that are affected by periodic inundation. Soil fertility is also maintained better on the arid hill slopes than in some of the more humid portions of the basin. Both the inter-Andean valleys and the cordilleras west of the Basin are, however, over-populated in relation to their resource base. Many areas that are basically marginal for agriculture are being cultivated, and soil erosion is serious. Out-migration of population seems to be the only effective long-term solution. In all probability these areas will supply many of the laborers and colonists that will move into the more favorable portions of the basin when development activities are implemented.

The lower tropical area of the Guayas Basin presents a sharp contrast to the two areas just described. While a few areas are densely settled, there are large zones of very high potential for agricultural development that are either uninhabited or only sparsely settled. This is particularly the case

1. This map was compiled on the basis of the 1960 census data and shows province and canton populations. While the location of population within the respective cantons is based on approximations, quantitative sum total canton figures are as accurate as the official census.

in the northern part of the Guayas plain, where large areas of highly fertile soils of the Pichilingue Association are found, but population is restricted to a narrow strip along the road from Quevedo to Santo Domingo de los Colorados. On the whole, the southern Guayas plain has a moderate density of population, but many favorable areas are still sparsely populated in relation to the productive capacity of the land.

Urban population in the Guayas plain presents a distinctive pattern. Population is centered on the flood plain largely at the junctions of river and road transport routes, which over the years have given rise to the establishment of fair-sized urban centers. Quevedo, Balzar and Babahoyo are typical examples. Their existence is due largely to the fact that they are collecting centers or points where goods are transshipped or where ferry facilities are provided to cross some of the major rivers of the region. Today they are prospering in various degrees due to the development of market facilities and food processing industries. Only Guayaquil, the principal city of the Basin, can boast considerable manufacturing or processing industries that supplement the heavy dependence on the agricultural activities of the region.

Three predominant settlement characteristics are evident in the tropical area of the Guayas Basin. The first is the relatively homogeneous distribution of population in the southern part of the Basin, where much of the land is already being cultivated. The second characteristic relates to the generally sparse population in the northern portion of the Basin; and the third relates to the rural population and urban settlements that have tended to agglomerate along rivers, streams and the road network throughout the whole area.

The map of population distribution clearly illustrates the varying population densities in the Basin, and when systematically compared to other maps showing over-all resource and agricultural potentials, it facilitates the diagnosis of environmental and human relationships. While more detailed elaborations regarding man/land ratios are presented in a later section, it is readily evident that if the resources base within an area is homogeneous but the population distribution supported by agricultural activities within that same area varies radically, an explanation is needed. The product of such analysis may indicate the proper direction of population readjustment and the need for emphasis on development in selected areas in order to encourage migration from overpopulated zones with unstable social and economic conditions.

Analysis of Land Use Patterns

Although the major portion of the Guayas River Basin is already utilized for the production of agricultural crops, much of this area is not utilized intensively (see the map Land Use and Forest Types in the Guayas Basin in Appendix F). Other portions are still covered with virgin stands of timber or are not being utilized because they suffer the effects of periodic inundation or lack of adequate drainage.

West of the Río Daule a large portion of the area in the Colonche and Chongón Cordilleras is devoted to perennials and tree crops such as coffee, cacao, tagua palm and castor beans. Farms appear to be small and many may be operating at a subsistence level. On the Daule floodplain, rice, cotton, sugar cane and maize predominate.

In areas of the southern portion of the Guayas Basin, largely between the Río Daule and the Babahoyo, land is cultivated for the production of rice. Bananas or cacao are also cultivated in the better drained areas but yields cannot be high without irrigation during the dry season. South and east of the Río Babahoyo a variety of tree crops are produced. In the extreme south, intensive sugar cane cultivation is found near Milagro where relatively sophisticated production techniques, including drainage and irrigation measures, are employed on some farms. Bananas and cacao are also irrigated. A fairly large total area of the southern flood plain is used only for pasture.

In the better drained and more humid northern portion of the floodplain, bananas are the predominant crop, and tree crops such as coffee and cacao are localized to valleys of slightly higher elevations that trend toward the Andean slopes. Fruits, tubers, and small grains characteristic of cooler climates are cultivated in the inter-Andean valleys and large tracts of forested land are found on the higher slopes of the cordillera. North of the foodplain of the Basin the natural forest cover predominates and little land is used for agriculture.

In general, land utilization throughout the Guayas Basin is characterized by a heterogeneous pattern. Aside from a few areas of intensive rice, banana or sugar cane production, most of the farming activity is extensive. In some areas shifting cultivation is practiced. Large tracts of pasture, forest and poorly drained land can be distinguished on the map,"Land Use and Forest Types of the Guayas Basin," and much of the land is in fallow.

There is a close correlation between land use and transport routes, both rivers and roads. This is evident particularly in areas along the foothills of the Andes where valleys are intensively cultivated even though the resources base of the locality is less than optimum. Adjacent to the strips of intensive agriculture are transitional zones composed of both agricultural land and lands still in virgin forest. There appear to be dynamic zones of settlement or spontaneous colonization expanding along the transport arteries. Similar situations are found along some of the rivers north and west of Quevedo. Land use patterns also reflect drainage conditions. The existence of tree crop cultivation bordering major streams in the badly drained terrain of the southern flood plain is probably due to the better drainage characteristics of natural river levees. Back waters tend to be marshy and are suitable only for pasturage or rice cultivation.

The conversion of much of the land not presently exploited to its maximum use should be the prime objective of development activities in the Basin. Ecuador at present is the largest exporter of bananas, and provides the world with 29 percent (33,000,000 bunches in 1961) of its supply. More than half of these exports originate in the banana producing areas of the Guayas Basin. The Basin also produces a large proportion of cacao for export (36,000 metric tons in 1961), as well as much of the sugar, coffee and food staples that are consumed within the country. The conversion of presently unexploited land to agriculture and the intensification of existing agriculture could have a major effect on both the local and national economies. The comparison of population totals as well as the distribution of population to areas presently utilized and those areas having a resource base well suited for agricultural utilization clearly indicates that the potentials of the Basin have not been exploited to their maximum.

Analysis of General Development Potential

Accurate estimates of the development potential of the Guayas Basin cannot be made without further qualitative and quantitative data regarding the natural resource base. However, on the basis of the reconnaissance data presented in previous chapters, general indicators regarding development potentials could be determined.

The areas within the Basin with the greatest agricultural potential are those with fertile soil, not limited by drought or poor drainage conditions, and where the rural population is still relatively sparse. The area already producing bananas, cacao and other tree crops could be expanded considerably to include tracts presently under virgin forest. The development of a more adequate infrastructure could also contribute substantially to the expansion of productive land. Improvement of farming techniques and the development of agricultural credit and other support to assure stable markets could also assist tremendously in bolstering the development of potential agricultural land.

The irrigation potentials of many parts of the Guayas Plain are also promising. In many parts of the southern portion of the Basin, the drought effects of a severe dry season could be ameliorated by utilization of surface water or by further extension and construction of feeder canals of existing irrigation works. Much of the area presently used for non-intensive agriculture could be irrigated and put under intensive crop production. Yields of dry land farming are frequently doubled or tripled when irrigated and managed carefully.

Groundwater potentials should be investigated where terrain conditions and gradients prohibit the diversion of surface water. Much of the lower flood plain has a high local water table where pumping operations would not be costly. Other sites, particularly along the Andean foothills, would appear conducive from the geological standpoint for encountering natural aquifers. The draining of saline or marshy lands could also increase the productive capacity of the Basin tremendously. Due to seasonal flooding and exceptionally low gradients, large tracts within the basin remain waterlogged for extended periods of time and resulting hydromorphic conditions limit their utilization. Drainage of such lands would substantially expand areas that could be used for agriculture.

Along with the development of land by irrigation or drainage, hydroelectric potentials should be exploited. Such possibilities exist along much of the western Andean slopes where gradients are steep and streamflow is relatively constant. Preliminary reports indicate that an abandoned hydroelectric plant on the Pilalo River could be rehabilitated, and several additional hydroelectric sites on the same river have been located. The development and settlement of the Basin will undoubtedly be accompanied by an increase in the demands for electricity.

Increasing needs for power and energy for industrial and domestic consumption in Guayaquil must also be satisfied. The demand for domestic fuels, for example, is presently met to some extent by wood and charcoal, however local wood supplies are limited, and increasing demand may bring about the over-exploitation of local forests. This could cause the degradation of productive forest lands and create serious erosion problems. A more satisfactory energy source will have to be developed, therefore. Power and energy needs for the city of Guayaquil could possibly be satisfied by utilizing natural gas in the Santa Elena Peninsula, which is an unused by-product of petroleum exploitation at the oil well sites. This possibility has already been anticipated by the Junta de Mejoras of Santa Elena and it should be given serious consideration in assessing the over-all power and energy possibilities of the Guayas Basin. The development of thermoelectric plants near Guayaquil, using natural gas as the energy source, and the direct consumption of natural gas for domestic and industrial purposes would alleviate the critical shortage of local mineral fuel resources. Moreover, the provision of Guayaquil's power and energy needs from this source would also enable a greater utilization in rural areas of the Basin of hydroelectrically generated power, which otherwise might have to be diverted in large part to the Guayaquil urban area.

The highest timber potential in the Guayas Basin is found in the area that includes evergreen and deciduous broadleaf forest species. Several alternative systems exist for exploiting these forests: by clear cutting in selected areas or by carrying out lumber operations on a sustained yield basis. The choice depends largely upon the degree of selectivity in cutting that is most desirable, this in turn being based upon the standing volume and distribution of growing stock and the economic considerations which could limit exploitation and utilization.

Because much of the high quality forest, particularly the evergreen broadleaf, is located on the land with good soils, colonization and agricultural development will undoubtedly lead to the deforestation of selected areas. The harvest of the commercial timbers found in these forests would provide an immediate source of income to colonizers and help finance land clearing operations.

If parcelization of forested lands is contemplated for colonization, the exploitation of the forest could be done by the new colonists, but the equitable division of the agricultural land should be based upon the potential productivity of the soil rather than the value of the growing stock.

It is in forested areas with less or demonstrably low agricultural potential, such as in the Oro latosols soil area, that a determination will have to be made of the best manner in which to manage the timber resources, either in combination with agricultural activities or solely as a forest exploitation. The relative degrees of agricultural productivity of the poorer soils will have to be determined in order to set aside those areas that should be maintained as forest reserves.

The best exploitation methods of forest reserves, once they have been demarcated, will require silvicultural experimentation, although experiences in other countries can serve as a guide to management.2/

In some areas where soils or climatic conditions will not permit intensive cultivation, forest exploitation could be combined with agricultural use by fallowing agricultural land for ten or more years after two or three years of cultivation. Another alternative would be to intensively exploit the forest over these soils and convert them to pasture, or to plant tree crops with low fertility requirements. In addition, plantations of high quality, (e.g., high-demand tropical species such as teak and balsa) could be established. In such marginal soil areas, great caution must be exerted so as to avoid practices that could permanently diminish the inherent soil fertility or they will eventually become degraded to the point of being able to maintain only a savannah type vegetation. Where such danger exists, and partial agricultural land use is contemplated, it will be absolutely necessary to maintain a considerable degree of vigilance and control over agricultural operations, and land owners will have to be educated in the conservation principles and techniques necessary for retaining the productivity of their lands.

Despite the high natural fertility of the soils that have developed over the forested Andean front, their exploitation for agriculture is limited by both steep slope and excessive rainfall. Management systems for both high and low mountain forests should therefore take into account the watershed function of the many valleys along the Andean front covered by these forests. The multiple use of watersheds for grazing and tree crops is possible but only if the vegetative cover necessary to control run-off is maintained. At best only selective logging operations should be permitted; tree crops and/or pure stands of commercial timber could perhaps be established, providing the conversion of the natural vegetation to such crops would not provoke erosion or landslides. The shifting agriculture taking place on these slopes should be investigated and controlled if evidence of accelerated erosion is found.

The western slopes of the Andes, particularly in the northern portion of the Basin, apparently have the highest mineral potential. There are indications of copper, gold and other minerals, but due to the overburden of volcanic deposition on the Andean slopes the location of prospects is problematical. The depth of sedimentation covering most of the Guayas Basin flood-plain decreases the metallic mineral potentials of that area, although good placer deposits may be located on the streams flowing out at the foothills. Deposits of ceramic clays exist but their economic importance is primarily local.

2. FAO has suggested several alternatives for exploiting mixed evergreen broadleaf forests on plateau clays in the Amazon Basin, where ecologic conditions are generally similar to those of the Balzar plateau and its Oro latosols. Highly selective cutting of two or three desirable species could be followed by enrichment planting of desirable species which are shade tolerant. Heavily selective cutting of all species having a certain minimum diameter could be followed by natural seedling regeneration, assisted by cutting back vegetation or undergrowth which compete for light or nutrients. Clear cutting could be followed by mixed or pure plantations of commercial species.

Demarcation of Development Regions and Sub–Regions

To provide a composite of the potentials of each of the respective natural resource factors (physiography, soils, forests, hydrology, etc.) and to relate such potentials to watershed areas as well as population distribution, pertinent factors were evaluated and superimposed in order to define specific development regions. The cartographic superimposition technique is illustrated by the map entitled, The Composite Evaluation of Natural Resources of the Guayas Basin (see Appendix F), which provided the basis for the definition of specific development regions.

Sufficient data was provided by use of this methodology to subdivide large development regions into subregions, each of which are relatively homogeneous in characteristics, possessing similar problems as regards resource exploitation and development. Some areas of high soil quality coincide or overlap areas of exploitable forest, favorable water resources or other potentials. Areas of over-all high quality could consequently be distinguished from areas of medium or low potential. These distinctions were then compared to the existing land use pattern and to the present population distribution within the Basin. The analysis and comparisons led to the compilation of the map, Development Regions of the Guayas Basin (see Appendix F). Boundaries of the demarcations of the respective areas of resource potential were then modified in order to maintain area homogeneity with respect to land capability. Consequently, the definition of development subregions could be established largely on the natural resource base. The economic connotation of "development" therefore refers primarily to resource or environmental potential for development in terms of agricultural or forest productivity and in relation to the number of people who can exist by the economic exploitation of these resources.

Economic activities related to mineral extraction and hydroelectric power that do not lend themselves as well to spatial analysis were nevertheless weighed into the evaluation. Due consideration was also given available qualitative data related to the apparent stage of development of transport and communication facilities, the approximate technological level of existing agricultural activities, the location of markets, and the accessibility of producing areas to markets. Other economic or political factors that might influence the region or subregion demarcations were not taken into consideration in the evaluation.

It is important to emphasize that the precision of regional and subregional demarcations is directly dependent upon the basic resource data and cartographic materials available to the field team. Thus, for some areas in which neither economic statistics, large-scale topographic maps nor aerial photography were available, the subregional analysis is only approximate. Many of the subregion boundaries are based upon extremely generalized information and imprecise data such as that gathered from low altitude aerial reconnaissance. Consequently, the area covered by some of the subregions does not reflect accuracy and detail of cartographic compilation, but without doubt exemplifies major local diversity due largely to the combination of resource factors.

On the basis of the methodology utilized in making the natural resources evaluation, three major development regions were established. These development regions are named in terms of the type of potential they hold: A. Agricultural Intensification Region, B. Forestry Region, and C. Colonization Region.

The regions include only those portions of the Guayas Basin with recognized development potential. Those areas of the Basin with low resource potential or that are presently overpopulated in relation to their natural resource base have not been included in the development regions. Thus, the subhumid Chongón and Colonche Cordilleras in the southwestern portion of the Basin, as well as parts of the western slopes of the Andes, have been eliminated in favor of the northern, central and lower portions of the Guayas Basin where the possibilities for more immediate, rapid development are greater.

On the basis of the development requirements for the specific development regions and subregions, each of which has similar natural resource characteristics, more precise definitions of over-all development possibilities and needed studies were formulated. Guidelines for the recommended development of natural resources are presented in detail in the following chapter.

CHAPTER IV

Guidelines for Resource Development in the Guayas Basin

On the basis of the preceding analysis of natural resources of the Guayas Basin, three major development regions, each of which is comprised of a number of subregions, have been established. Following are guidelines for the development of these regions.

Development Region A : Agricultural Intensification

Development Region A, comprising some 1,136,125 hectares, is made up of five subregions, each of which can be more fully utilized by investments in infrastructure particularly related to water resource development. The five subregions have been demarcated on the basis of distinct physical characteristics and varying cost-benefit ratios estimated for project development. The over-all development of Region A focuses on the utilization of groundwater potentials and more intensive exploitation of surface water for irrigation, as well as the establishment of drainage facilities and some flood protection. In some areas, irrigation projects can be oriented toward the production of bananas and other tree crops; in other areas they can be oriented toward sugar cane cultivation, or the production of rice. Several irrigation projects within the area are already partially developed, but further development aimed at intensifying agriculture should be a major goal for the region.

The irrigation needs of Region A are dictated by the comparatively long and intense dry season that affects the area. Drainage problems are, to varying degrees, common to all the soils of this region, as they coincide geographically with the flood-plain portion of the Basin. Fairly large areas are tentatively believed to be irrigable with surface water. There is a noticeable variation in soil characteristics, such as inherent fertility and texture, but these variations are generally subordinate to the limitations posed by soil drainage problems and seasonal conditions of soil drought.

The affirmation of the importance of irrigation and drainage in this region, and the tentative delineation of possible irrigable zones, does not constitute sufficient justification for the direct implementation of development programs in the area without further investigations. While present agriculture could undoubtedly be greatly benefitted from irrigation alone, and may be retarded by the lack of irrigation and drainage measures, there are other limitations of equal importance. These are related to the existing tenure characteristics, educational level of farm operators, transportation and marketing facilities, and agricultural credit services available in the region. These factors are operative to some degree within the present developmental pattern of this region, and it would be irresponsible to suggest that detailed studies of irrigation potential and development be made without first introducing the economic, social and institutional factors into the analysis. Viewed at a reconnaissance level, these factors should be compared to the available resource data to permit making more accurate definitions of projects for economic development. Guidelines for the logical development of projects in the respective subregions are presented in the detailed discussion of the individual subregions.

1. Subregion A.1

This is the only portion of the Agricultural Intensification Region in which resource development programs are underway on a significant scale. Subregion A.1 is considered as being closer to achieving its development potential and therefore deserving of high priority in programming development.

Area and population

The area of subregion A.1 is 148,500 hectares. The average density of its 32,800 rural inhabitants is 22 persons per square kilometer (see Table 6). The rural populace is somewhat concentrated in and around Milagro and Manuel J. Calle, two large irrigation centers, and along the railroad and other road routes. Population is sparse in river interfluves and in the extreme southwest of the subregion where forested areas are reported to be found.

Climate and resources

This subregion has a Tropical Moist climate with a six month dry season from June to December, during which time irrigation is needed. The area is favored by inherently fertile soils (the Naranjito Association) with no serious drainage problems, productivity being limited only by seasonal lack of water. Surface water supplies are restricted to the streamflow of two of three major streams flowing from the Andean front, the Chimbo and Cañar Rivers in particular.1/ There are geological reasons for believing that the coarse sediments of the piedmont near the Andean front hold an excellent potential for groundwater.

Development programs already underway are the Milagro and Manuel J. Calle irrigation projects of the Caja Nacional de Riego. The two projects have so far brought a total of 3,400 hectares under irrigation and are producing two major export crops, sugar cane and bananas, and by the time they are completed will furnish water to 25,000 hectares. The progress of these two projects has been slow due to lack of financing, total planning, and adequate technical assistance at the farm level. Unirrigated areas produce tree crops, near the piedmont, and perennial and field crops, to the west.

1. The course of the Cañar River, which has not yet been accurately located on available base map materials, traverses the extreme southern portion of subregion A.1 roughly parallel to the Bulubulu River.

Table 6

AREA AND POPULATION OF THE GUAYAS BASIN BY DEVELOPMENT REGIONS

Development Regions and Sub-Regions	Area in Hectares	Total Rural Population	Rural Man/Land Ratio (Persons/sq.Km.)	Area in Hectares with High Rural Population Density [b] in Hectares	Rural Area High Density Man/Land Ratio [b/ c] (Persons/sq.Km.)	Total Urban Population
A. Ag. Intensif. Totals	1,136,125	289,300	--	--	--	646,764
A.1	148,500	32,800	22	--	--	33,998
A.2	88,875	36,000	40	--	--	3,500
A.3	379,000	121,700	33	--	--	43,766
A.4	391,750	71,900	18	--	--	565,500
A.5	128,000	26,900	21	--	--	--
B. Forestry Totals	241,000	21,900	--	--	--	1,500
B.1	85,875	5,300	6	--	--	--
B.2	155,125	16,600	10	--	--	1,500
C. Colonization Totals	767,250	101,100 [a]	--	50,250	--	37,900 [d]
C.1	108,000	3,700	3	--	--	--
C.2	159,500	22,400	16	22,750	70	23,300
C.3	98,875	3,200	3	--	--	--
C.4	85,250	19,800	30	13,250	85	1,500
C.5	206,125	37,100	20	14,250	75	13,100
C.6	109,500	14,900	13	--	--	--

a. Does not include demarcated zones of high density rural population.
b. Over 50 persons per square kilometer. Measured only for Region C (Colonization). See demarcated zones on Development Regions Map.
c. Calculations did not include urban population encountered in these zones.
d. Includes urban centers found in demarcated zones of rural concentration.

Development

Agricultural intensification and higher production could be greatly aided through further irrigation in this subregion. Development planning should therefore contemplate the maximum use of surface and subsurface water resources for agriculture. The most obvious immediate measure to be taken is to invigorate and speed the development of the Manuel J. Calle and Milagro irrigation projects by securing adequate financing from international or national sources. The two projects have achieved less than one fifth of their irrigation goals. Maximum agricultural production and water use on these two projects as well as future works, can be guaranteed only by providing for central management of water use and distribution networks to the level of the individual farm; this will require construction of secondary and tertiary canal networks, lining of canals to prevent infiltration losses, and levelling of land on individual farms, where irrigation by flooding is practiced. If a move is made to obtain funds for the rapid completion of these projects, it would be unwise not to contemplate the construction of these additional facilities, none of which have been considered heretofore by the Caja Nacional de Riego.

Irrigation development in other areas will be dependent to a great extent on the availability of groundwater sources. These must be investigated before more detailed estimates can be made of such development possibilities.

The development of irrigation will not automatically intensify agriculture. Social and economic conditions not studied in the present report will be of equal importance. Factors such as minifundia (excessively small holdings), educational levels, and population movements may be of sufficient importance to influence to a significant degree plans for development based upon more technical considerations. The characteristics of the population and the local economy should definitely be introduced into further planning and must be studied.

Suggested studies

In the areas of the Manuel J. Calle and Milagro projects, the following studies are recommended: Detailed soils and land capability surveys, detailed land use investigations, including case studies of different sized farms, and detailed cadastral or property identification maps. Detailed topographic maps should also be made to facilitate the water distribution and canal construction plans. Whether or not additional financing is solicited, these studies are imperative for purposes of administration and management of the irrigation systems. It is also recommended that socio-economic studies be carried out in conjunction with and as a complement to the resources investigations. For the area as a whole, hydrologic studies are recommended in order to better measure the available surface water resources as well as to determine the existence and quantity of groundwater.

2. Subregion A.2

Subregion A.2 has abundant and well distributed surface water resources as well as a high potential for groundwater. These characteristics, combined with good soils and fairly large extensions of irrigable terrain, make this subregion one of high development potential.

Area and population

A rural population of 36,000 is distributed over the 88,875 hectares of this subregion. This makes for a relatively high density of 40 persons per square kilometer, although settlements are concentrated principally along the Catarama-Zapotal River and various roads and trails which cross the area.

Climate and resources

Yearly rainfall is around 2,500 millimeters throughout the subregion, however differences in vegetation indicate that conditions are more humid in the northern part. While in the south a dry season as marked as in subregion A.1 occurs, and irrigation is needed during six months, the northern portion may require irrigation for only four or five months. The area has the same fertile, well-drained soils as A.1 and its groundwater and surface water potentials are high. Total streamflow may be twice that of subregion A.1 and therefore sufficient for the estimated 40,000 hectares in this subregion that are judged to be irrigable. Except for small areas in deciduous broadleaf forest along the Catarama River, A.2 is entirely under cultivation, principally tree crops such as coffee, cacao and bananas.

Development

The resources of this area are very favorable for the development of irrigated agriculture. As the rural population is already quite dense, it is probable that irrigation will not only be desirable but necessary in order to raise production and the over-all standard of living in this zone. This subregion is serviced by roads that link it to the densely settled highlands and there is probably a good demand for its tropical agricultural products in the highland markets.

Suggested studies

To better determine the irrigation and general development possibilities of A.2, it is recommended that the following surveys be undertaken: Detailed soils, land capability and use studies; land tenure studies; and a hydrologic investigation of the subregion and its watersheds.

3. Subregion A.3

This large subregion, which embraces important banana producing zones, requires extensive drainage works as well as irrigation. Its development will therefore be more costly than the more favorable A.1 and A.2 zones.

Area and population

Over the 379,000 hectares of subregion A.3, its 121,700 rural inhabitants are distributed at an average density of 33 persons per square kilometer. The rural population is fairly evenly distributed, although settlements tend to be concentrated along roads and river banks, due to ease of transportation and perhaps better soil drainage conditions over natural levees.

Climate and resources

Irrigation needs in subregion A.3 are as great or greater than in A.1. Dry seasons last from six months in the northern and eastern portion to perhaps eight months in the south near Guayaquil, where a Tropical Dry climate prevails. Irrigation possibilities are reduced by soil drainage problems and lack of sufficient surface water. In the Vinces-Babahoyo interfluve, hydromorphic soils of the Vinces-Association occur as isolated patches within areas of better drained soils. The erratic stream patterns of this zone further reflect flat relief and slow run-off. Surface streamflow does not originate for the most part on the Andean front, as is the case for subregion A.1 and A.2, rather from run-off of seasonal rainfall occurring over the portion of the Basin covered by A.3. Surface water supplies are correspondingly reduced during the dry season. Irrigation development is therefore largely dependent upon the successful tapping of underground water resources and the provision of drainage works, the costs of which are liable to be comparatively high.

Development

Development through irrigation and drainage, while possible, is probably not practical for the entire zone. It is more likely that selected zones within this large subregion will present fewer limitations to the feasibility of such development. The Caja Nacional de Riego is presently studying the reservoir capacity of a depression near the town of Vinces known as the Abra de Mantequilla, which could provide water for perhaps as much as 70,000 hectares. The principal drawback would be the need for constructing costly drainage works; these could exceed the irrigation distribution networks in cost. It cannot be concluded therefore that the possibility of impounding large amounts of water is the key factor in determining irrigation feasibility in this poorly drained zone. Furthermore, the maintenance of a large irrigation project may be very difficult if there is a tendency for this zone to be seasonally inundated. One bad flood could bring about costly damage to irrigation and drainage networks and crops. Small-scale rather than large-scale reclamation and irrigation projects are therefore recommended for future development.

Suggested studies

The successful intensification of agriculture through irrigation in subregion A.3 will depend to a great extent on drainage possibilities and costs. These must be determined for use in the early planning stages and it is recommended that semi-detailed soils and land capability and land use studies be undertaken, in addition to land tenure studies. More should be known about seasonal fluctuations in streamflow, and flood danger and frequency. A reconnaissance of the surface hydrology of the area is therefore recommended. Reconnaissance socio-economic information should also be gathered in order to better orient planning.

4. Subregion A.4

This large and relatively sparsely populated subregion has good road and river transportation facilities which link it to near-by Guayaquil markets, however, unfavorable soils and climatic conditions constitute severe limitations to agricultural development.

Area and population

This is the largest of the subregions in the Agricultural Intensification Development Region with 391,750 hectares. The low productive capacity of A.4 is reflected to a certain extent by a rural population density of 18 persons per square kilometer, the least of any of the subregions in this Development Region. Population is especially sparse in the zone adjacent to, and radiating outward from, Guayaquil for approximately 20 kilometers. Particularly severe limitations to agricultural productiviy must exist in this zone, since ordinarily areas adjacent to large urban centers are intensively cultivated in truck crops for urban consumption. On the other hand, rural population is fairly heavily concentrated north and east of the town of Daule, in an area of apparently serious drainage problems. This can be interpreted as resulting in fairly low standards of living in this particular area, which may be causing movements of the rural populace into Guayaquil.

Climate and resources

A.4 has a Tropical Dry to Very Dry climate with a dry season of at least eight months near Guayaquil. Irrigation is thus imperative for intensified agriculture. Soils are principally the black clays of the Daule Association which are poorly drained and, south of Daule, saline from tidal waters. Scattered remnants of scrub forest of no commercial importance are found near Guayaquil. The interfluve of the Daule and Babahoyo Rivers is generally subject to seasonal inundations when the combined run-off of these rivers increases during months of heavy rainfall in the upper watersheds. The generally low relief of this subregion also imposes limitations on the impoundment of water for irrigation use,and the slight gradient of the Daule River further increases difficulties in reservoir construction. These physical limitations are counterbalanced in part by the proximity and accessibility of this subregion to Guayaquil.

Presently the subregion is cultivated in rice, which produces good yields, and mixed food crops. Large areas are used for pasture, probably where drainage conditions do not permit cultivation of the soil.

Development

The most rational approach to increasing agricultural production in this subregion is through the development of local projects oriented to specific problems of soil drought or drainage. Irrigation with ground water in the sparsely populated area contiguous to Guayaquil will probably be impossible due to the salinity of surface as well as subsurface waters, a typical circumstance in coastal areas. The impoundment of water in the vicinity of Balzar (see Fig. 9) would make it possible to irrigate lands along the Daule River not affected by salinity, although soil drainage problems would still have to be solved. Until the feasibility of correcting soil drainage limitations by extensive engineering work is proven, it would be unwise to proceed with studies for construction of large reservoirs, even though these may be possible. It may be more economical to pump underground water from numerous small wells located in areas with the least soil drainage problems. It will therefore be necessary to make studies of the various alternatives for correcting soils limitations and exploiting surface or subsurface water, in order to arrive at the most economical solutions for intensifying agriculture. In addition it will be necessary to weigh soils and water development costs with the present and projected needs for high bulk food staples and perishable crops, whose transportation to Guayaquil from more distant areas becomes costly but may nevertheless be cheaper in the long run than the investment of large sums to increase production of such crops in this subregion.

In conclusion, the over-all feasibility of costly development schemes for subregion A.4 is doubtful and should be undertaken only after a cautious evaluation and comparison of the potentials of this subregion with that of other subregions with less physical problems to resource development.

Suggested studies

For the present it is recommended that semi-detailed soils surveys be undertaken, with special emphasis on physical characteristics affecting irrigation practices and climatic conditions which determine irrigation needs. In addition, semi-detailed land use and land tenure studies are recommended. These will provide information useful to agricultural extension and promotion activities as well as serve to focus on agricultural problems in this subregion, which may be related to urban problems in Guayaquil caused by migration of rural dwellers to that city.

5. Subregion A.5

The role of this subregion in agricultural intensification will be a complementary one, as its resources and location indicate that future development should be oriented primarily to watershed management for the benefit of the dry areas in the Guayas Plain that are watered by the rivers and streams passing through it.

Area and population

Subregion A.5 is comprised of the lower slopes of the Andean front representing an area of 128,000 hectares. The total rural population is 26,900 giving an average density of 21 persons per square kilometer. Settlements are distinctly concentrated along rivers and roads descending from the Sierra and traversing this subregion.

Climate and resources

Subregion A.5 has a Tropical Moist climate with about a six-month dry season, although to the south there is probably fog during periods of low rainfall. In the northern portion of the subregion rainfall is heavier and a Tropical Wet climate with a four or five month dry season is found. This northern portion is entirely forested (low mountain forest) although it is doubtful that significant quantities of commercial species have escaped logging activities. In the south tree crops are cultivated and lesser areas of forest exist. In essence, A.5 is composed of the middle portions of numerous isolated watersheds. The streams passing through this subregion have steep gradients and present certain possibilities for small hydroelectric sites. Steep gradients and narrow valley floors limit reservoir possibilities, however.

Development

The watershed function of A.5 should receive special attention. It will be necessary to maintain an adequate crop or other vegetative cover in order to control erosion and prevent excessively rapid surface run-off which could cause flooding in the plain, and which, in addition, could mean the loss of valuable irrigation water needed at lower elevations in the Guayas Plain (see discussion of subregions A.1 and A.2). Although rainfall is not as intense as the orographic precipitation occurring at slightly higher elevations, erosion is nevertheless a danger in steeply sloping terrain during the six-month rainy season.

The fertile volcanic soils (Maná Association) that occur on these slopes will produce good yields, and in the southern portion of A.5, which is well serviced by road and railroad, land is under cultivation. The existence of forests in the north is probably due to lack of road transportation and distance from Guayaquil. The goals of further agricultural development on the hilly terrain of A.5 should be subordinated to the dictates of watershed management and it will be necessary to determine in which areas agriculture can be permitted and what crops and techniques must be employed to conserve soils and control erosion and run-off.

Suggested studies

This subregion will probably continue to undergo settlement, even if there is no government guidance or participation. For that reason, it is imperative that the needed conservation measures be determined in order to control land use activities and preserve the watershed value of this subregion. It is therefore necessary to conduct soils and land capability, land use and land tenure studies at a semi-detailed intensity. In addition to providing information for watershed management, these will enable a more precise determination of the agricultural potential of this zone, which was considered to be low primarily due to steep slope. It is likely, nevertheless, that productive capacity on less steeply sloping soils is high for certain tree crops, given the proper soils management.

Development Region B : Forestry

Development in Region B focuses on the exploitation of forest potentials under management methods that assure continued production. Region B, totaling 241,000 hectares, is comprised of two subregions, each of which can be managed for the production of commercial timber. While the Forestry Region depicted on the map is of limited size, it extends beyond the Guayas Basin. It is characterized by soil or terrain conditions which pose severe limitations for agricultural land use and limit development to forest exploitation. Good soil areas that are presently covered with forests have not been included in this Region since most of such land will be cleared before long and in all probability will be utilized strictly for agricultural purposes. Thus, the evergreen broadleaf forest found on the Pichilingue Soils Association will be harvested when land is cleared, and it is not included in the Forestry Region. The rural population is sparse to moderately dense in Development Region B (see Table 6), but because no aérial photographs of this relatively inaccessible area were available, no detailed land use or settlement patterns information could be obtained. However, the majority of this Region appears to be under dense forest cover.

Both evergreen and deciduous broadleaf forests predominate in this latosolic soil area. In the northern portion remnants of an old plateau are still in evidence. Further to the south, however, where the easternmost extension of the Balzar Cordillera lies adjacent to the Guayas Plain, the hill slopes have been severely dissected by the tributaries of the Daule River. Some of the forested area in the plateaus and hill land is characterized by poor soil drainage conditions, leading to the development of soils that produce no commercial timber.

The Forestry Development Region has been divided into two subregions: Evergreen Broadleaf Forests (B.1) and Deciduous Broadleaf Forest (B.2). The dividing line serves to locate in a most general manner the transition zone between these two forest types. It indicates a decrease in annual moisture and an increase in the length of the dry season toward the west, rather than temperature or altitudinal change.

1. Subregion B.1

Evergreen broadleaf forests predominate in this subregion. It has the highest potential yield of commercial timber per hectare in the Guayas Basin. Furthermore, it is readily accessible to markets in that the area is adjacent to areas that will in all probability be settled and developed in the near future.

Area and population

The area of Subregion B.1 totals 85,875 hectares. The average density of its 5,300 rural inhabitants is 6 persons per square kilometer. The rural population is extremely sparse and families are settled primarily along several small rivers in the northern portion of the area. The majority of the area is uninhabited.

Climate and resources

Yearly rainfall over Subregion B.1 is approximately 2,500 mm. There is no serious dry season and low, depressed terrain is likely to be permanently wet. Such wet spots can be identified by the existence of palms and other species of noncommercial value. A substantial volume of timber is found on well drained sites, but even in these areas a discontinuous crown canopy indicates the existence of a thick and tangled understory more typical of poorly drained sites.

The forests on well drained soils may have as much as 45,000 board feet of timber per hectare, although per hectare volumes of 25,000 board feet are more representative. The soils found in the Subregion are the latosolic clays of the Oro Association, which have very low agricultural capabilities.

Development

The principal limitation to the profitable exploitation of the evergreen broadleaf forests appears to be the regional characteristic of poorly drained terrain, which reduces the total area of commercial timber and complicates the transportation of logs to sawmills. The next step in investigating these forests is the aerial photointerpretation of the forest region to more clearly define the degree and extent of poorly drained terrain and to delimit forest types with large, well formed canopies on well drained sites prior to performing ground observations.

In the event that land under this forest type is cleared for agriculture, it is highly probable that the soils will eventually be converted to pasture use, since high rainfall and low soil fertility in this region preclude continuous cultivation without fertilizers. The use of fertilizers may be uneconomic where soil leaching action is intense.

Parts of the evergreen forest have been cleared along the road leading from Santo Domingo to the coast. Feeder roads leading into this major market route will undoubtedly continue to provide the best access to the region for future logging operations. However, if after further investigation it is determined that commercial timber in this forest type is found in scattered localities, use of tributary streams of the Daule River may prove more feasible than the construction of more extensive feeder roads for extracting logs. Only the results of a forest inventory would provide information as to which route would be utilized in the exploitation of the forests and where future sawmills should be located.

Suggested studies

An exploratory forest inventory is recommended for the purposes of more accurately determining the location, volume and types of commercial species found in Subregion B.1. Ground sampling intensity should be at least 3 percent. An inventory at this level of intensity will provide the information required for justifying more detailed inventories and sustained yield management studies. It will also provide data relevant to planning transportation and plant facilities for timber extraction and utilization.

It is recommended that the exploratory inventory be conducted along lines similar to the FAO forest inventory presently being carried out in the Esmeraldas region to the north of the Guayas Basin. This will enable a correlation of data and increase the significance of economic interpretations for regional planning purposes.

2. Subregion B.2

The timber volumes estimated for the broadleaf deciduous forest of this Subregion are only slightly lower than those of the evergreen forest of Subregion B.1. The relatively greater inaccessibility of large areas of B.2 and its location on rough terrain constitute sufficient reasons for assigning a slightly lower potential value to the forests of this subregion.

Area and population

Subregion B.2 covers an area of 155,125 hectares, almost twice the area of B.1. Its forests actually grow over the highly dissected drainage divide between the Guayas River watershed and watersheds to the north and west which are covered with similar forest types, although beyond the confines of the Guayas Basin.

As is the case in B.1, no towns of significant size are found in this subregion. Average rural population density is somewhat greater, with about 10 persons per square kilometer, although in actuality the majority of the 16,600 rural inhabitants of B.2 are settled principally along the southern frontier from which settlers are advancing northward from the lower Guayas Plain. Most of the subregion remains uninhabited. The drier climate is more favorable to human habitation and subsistence farming than in B.1. and spontaneous settlement can be expected to continue.

Climate and resources

Yearly rainfall increases from some 1,700 mm. in the south to about 2,000 mm. near the western limits of B.1. The composition of the deciduous broadleaf forest in this highly dissected zone is likely to be highly variable owing to rainfall and terrain differences, which result in differences in soils and available moisture that are important to vegetation development. Timber volumes are estimated at 20,000 board feet per hectare. There may be a higher percentage of species with outlets on local markets, as this is the type of forest which has been exploited in areas to the south of Quevedo.

Development

Although the soils of Subregion B.2 are judged to be poor, the relatively dry climate permits subsistence-type agriculture which is not successful in the more humid B.1 zone. For this reason, particular attention should be given to excessive deforestation carried on by agriculturalists who are attracted to this zone. At the earliest date an accurate determination of the timber reserves of B.2 should be made in order to take the steps necessary to prevent the wasteful clearing of commercial forests. Improper agricultural practices could bring about considerable soil loss and a possible degradation of the land to a savannah-type landscape.

Although the forest resources of B.2 cannot be expected to renew themselves as rapidly as those of B.1, due to less rainfall, forest management will will nevertheless be based upon the same general consideration pertaining to the evergreen broadleaf forests. The assignment of silvicultural work will have to bear some relationship to the possible degrees of exploitation and utilization. In essence, the same information must be obtained about these forests as that needed for Subregion B.1.

Suggested studies

It is recommended that the exploratory inventory to be undertaken for B.1 include the B.2 area and that the same intensity of ground study be made. Thus, the entire Development Region is recommended for an exploratory forest inventory, as specified in the studies suggested for B.1.

Development Region C : Colonization

Development Region C is centered on sparsely populated or still uninhabited lands of high productive capability. The resource base of the area indicates that the carrying capacity of the land could be increased without major capital expenditures in irrigation or drainage measures, as was the case for Region A.

Region C, totaling 767,250 hectares, is comprised of six subregions, each of which possesses unique characteristics that are specifically, and in some cases, ideally oriented to colonization and settlement. In addition to being only sparsely populated and not requiring major investments in irrigation and drainage works, the region has high quality soils with few limitations to agriculture, terrain conditions conducive to relatively small family-size farming operations, and in general relative accessibility to major roads and markets. Furthermore, the Government of Ecuador has already initiated colonization activities in some sections of the Region. While some of these sections already support a fairly dense rural population, it is evident that the land capability of the region is high and could support many additional settlers. At present much of the land adjacent to the roads has already been cleared and put under cultivation. Bananas and cacao are the major commercial crops grown in the area.

The Region is bisected by a major transport artery that runs from Santo Domingo de los Colorados to Quevedo and continues southward to Guayaquil. From Santo Domingo de los Colorados as well as Quevedo, roads ascend the Andean Cordillera and connect the region to Quito and the highlands.

The subregions that were included in the Colonization Region were defined on the basis of soil quality, timber potentials, geomorphic and climatic factors as well as those related to minerals and hydroelectric potentials. These physical factors were then related to population distribution and density. In accordance with other investigations of similar tropical environments, an estimated 15 hectares of land is sufficient to support a farm family (average of 5 persons), or 35 persons per square kilometer, and would provide land for some commercial crop development as well as subsistence food production. Thus, the rural population in each of the subregions could theoretically be greatly increased, particularly in Subregions C.1 and C.3. In addition, land capability could be further increased by improvement of existing agricultural techniques, development of agricultural credit services and related facilities. The areas with population densities of over 50 people per square kilometer (1 person/2 hectares) were demarcated and eliminated owing to their lesser capacity for additional agricultural settlement.

1. Subregion C.1

This Subregion probably has the highest agricultural potential of any area within the Guayas Basin due to its favorable climate and excellent soils. Also since it is mostly uninhabited and is still in primary forest it has an excellent colonization potential, which is enhanced by the possibilities of realizing immediate returns from the harvest of its timber products.

Area and population

C.1 is separated into two sectors which have a total area of 108,000 hectares and are located on either side of the Santo Domingo de los Colorados-Quevedo road. Both sectors could be connected to that important route by feeder roads. Most of the 3,700 rural inhabitants in C.1 are settled east of the road along streams descending the Andean slopes. Virtually no settlements exist in the western sector. The C.1 area could probably support as many as 5,000 families.

Climate and resources

C.1 has a Tropical Moist climate with about 2,500 mm. of rain per annum and a four month dry season. The fertile Pichilingue soils occur throughout C.1 and its forests have timber volumes ranging from 20,000 to 45,000 board feet per hectare, although significant portions of poorly drained sites produce no commercial timber.

Development

Prior to settlement, substantial income can be derived from the exploitation of the Subregion's timber resources. Guidance should be provided to assure the fullest possible utilization of these resources. Soils and climatic conditions are especially favorable for such tree crops as African oil palm, cacao and bananas. The cultivation of annual field crops is limited only by the effects of the abundant rainfall of the region. The practice of clean cultivation which exposes the soils to the leaching effects of rains, will eventually deplete soil fertility. For this reason it is important that the agricultural development of the Subregion receive adequate technical guidance, which can probably best be afforded as a part of a colonization program.

The Ecuadorian government has already demonstrated its intent to consider the general region as a colonization development area. It is therefore suggested that more intensive studies of soils and timber resources in the area be performed so as to provide data as quickly as possible for use in planning colonization. The objectives of soils and forest surveys should be formulated in accordance with colonization procedures and it will be necessary to determine beforehand the methods and policies to be followed in settling the C.1 area, particularly with regard to the forest exploitation and land clearing phase. The forest resources could be exploited by a large logging company or by the colonists during the process of land clearing.

While forest exploitation by a private logging company would probably be more efficient, it is questionable whether this is in the best interests of land colonization. The heavy equipment that is used to extract logs from the forests tends to break down soil structure, an important consideration in this high rainfall zone where good internal drainage is needed. If settlement does not immediately follow logging operations, vigorous regeneration of second growth will create great difficulties to land clearing operations as well as to the conduct of detailed soils studies, if these are to precede settlement.

Finally, the profits to be derived from the exploitation of the timber resources would most likely have greater social benefit if they were received directly by the colonists, rather than indirectly through government taxation of wood products and eventual allocation of such funds for colonization purposes. This initial income would not only contribute to making the colonist active in the local economy but would strengthen his sense of independence and responsibility as a land owner. It is therefore strongly recommended that future colonization projects be planned so as to allow the individual colonist to harvest and sell the timber on his allotted parcel of land.

Suggested studies

The successful colonization of C.1 will require studies prior to settlement for establishing an over-all plan, as well as investigations during the course of actual settlement to enable farm management planning. For the purposes of initial planning, semi-detailed soils and land capability studies will be required to locate zones with the highest agricultural capabilities. Terrain conditions and the navegability of the rivers in the area should be studied for planning transportation routes. These studies will provide a basis for more accurately estimating the settlement capacity of the area and for dividing the Subregion into several blocks or zones which can be treated as separate settlement projects. An exploratory forest inventory should be made based on photointerpretation and sufficient ground sampling (3 percent or more) to permit fairly accurate estimates of the extent and volume of marketable timbers.

Immediately prior to settlement activities, detailed soil surveys should be performed to permit an equitable determination of parcel sizes based on soils capabilities and to provide a basis for recommending crops and soil management practices. One hundred percent forest surveys should also be conducted at the same time with the purpose of marking commercially valuable trees as a guide to the colonist when he begins logging and land clearing operations. These detailed phases of the soils and forest inventories could be carried out in accordance with the settlement schedule, so that the data become available as needed. This procedure has the advantage of providing on-the-job training over a period of time to local technicians, who could eventually assume all of the responsibilities for carrying out these surveys.

2. Subregion C.2

This Subregion combines the same highly favorable soils and climatic conditions as C.1, however its potential for colonization projects is slightly diminished because it is already in the process of settlement. Further development will entail measures closely related to the process of colonization, however, especially with respect to the need to establish ownership rights of recently settled families.

Area and population

Subregion C.2 has a total area of 159,500 hectares, 22,750 of which have a dense rural population of 70 persons per square kilometer (see demarcated high density area shown on Development Regions map). The remainder of the Subregion has a total of 22,400 rural inhabitants, or 16 persons per square kilometer, who live in settlements bordering major roads and rivers.

Climate and resources

Yearly rainfall is around 2,500 millimeters and the dry season lasts approximately four months. The soils are the same fertile loams of the Pichilingue Association found in C.1. No significant forest areas remain to be exploited and most of the zone appears to be under banana or cacao cultivation.

Development

The agricultural development of C.2 should be oriented toward planned colonization. In those areas of the Subregion where actual settlement has already taken place and *de facto* land ownership has been established, the settlers should be given guidance and assistance in making their operations successful. The legalization and definition of ownership rights and property boundaries should receive first priority. Uninhabited public lands should be reserved for planned settlement. Until the extent of these is determined, it is impossible to state the number of families who could participate in official colonization projects. In such a rapidly developing area, however, it is highly probable that large tracts of land have been claimed by speculators who have no intention of actually working their land. These areas may therefore be unavailable for immediate settlement; however, in fiew of the high productive capabilities of the soils in the Subregion, official measures should be taken to insure that all land undergoes agricultural development commensurate with its potential productivity.

Technical assistance and agricultural credit will be needed to raise production and adjust agricultural practices and crop types to local soil capabilities in already settled areas. Shifting cultivation, which is probably practiced by farmers with small resources and little education, should be halted. In summary, the agricultural economy and land tenure structure of this newly developing area must be stabilized and adjusted before effective development can take place. This means planning and guiding present and future settlement so as to achieve the sustained and high levels of production possible in this area.

Suggested studies

A variety of investigations are needed to accomplish the above settlement and development measures. Detailed soils and land capability studies are needed over the entire area for agricultural planning, technical assistance, and colonization planning. Detailed land tenure and land use studies are needed to establish property boundaries and define the extent of public lands actually available for further settlement. The information from these studies will help to determine the scope and orientation of official participation in colonization projects and agricultural planning.

3. Subregion C.3

Although Subregion C.3 is presently uninhabited and covered with forests, its potential for colonization is less than in C.1 or C.2 due to the generally lower capabilities of its soils.

Area and population

Subregion C.3 has an area of 98,875 hectares, and its 3,200 rural inhabitants are settled chiefly along the Peripa River. There are no roads and the Peripa River appears to provide the only ready access to the interior of C.3.

Climate and resources

Yearly rainfall ranges from 3,000 mm. in the north to 2,000 mm. in the southern portion of C.3. The area is covered with evergreen broadleaf forests which tend toward deciduous forests to the south. The capabilities of the soils in the Subregion (the Balzar Association) are variable due to the rainfall regime, as well as to slopes, which range from moderete to steep.

Development

Settlement of Subregion C.3 would probably be rapid if adequate roads linked it to the Santo Domingo de los Colorados-Quevedo route. Spontaneous settlement is very likely to occur, even without roads, as colonization and development in C.1 increase accessibility to C.3. An over-all development and settlement plan should therefore be established in order to guarantee the rational exploitation of the forest and soil resources and prevent damaging land use practices. Such a plan could best be formulated in conjunction with the colonization projects developed for Subregions C.1 and C.2, which are adjacent to C.3.

It appears feasible that a mixed agricultural—forest products economy could be developed, with farm planning based on local variations in soils capabilities.

Previously established farm sizes based on scientific determinations of land capability will be necessary to avoid the tendency of colonists to establish small farms which will be abandoned as soils become infertile, occasioning the progressive deterioration of the soil resources as a shifting cultivation pattern becomes established.

While the steeper lands should be left in forest, agricultural development will be possible on the better alluvial and river terrace soils. Considerable variations in agricultural capability of soils are likely to be found over short distances where terrain and erosional processes cause difference in texture and fertility. In this high rainfall area, the maintenance of soil fertility will be more difficult than in C.1, and natural fertility should be a major factor in assessing land capability.

The successful operation of a mixed forest—agricultural family farm on a commercial basis requires fairly sophisticated techniques of land use management and a correspondingly adequate understanding of ecologic principles on the part of the farm operator. So far as is known there exists no precedent for such an operation on a commercial basis and on a family size property. Experiments in Africa in forest fallow techniques have indicated that such a system is possible in the humid tropics. Forest fallow would, however, preclude the possibility of managing small plots of forest for the extraction of commercial timbers since their maturation period exceeds the number of years of fallow necessary to restore fertility to levels enabling a return of the land to agriculture. These ecologic problems, which have been of great concern to land use specialists in tropical regions, are extremely complex and require serious consideration and investigation.

It is recommended that the same procedures for land clearing and colonization be followed as those recommended for Subregion C.1. Land settlement, however, will have to be prohibited in areas with low agricultural capabilities. These areas should remain in forests to be exploited on a sustained yield basis, perhaps by private logging companies or by community logging cooperatives managed by the colonists.

Suggested studies

The same studies recommended for C.1 should be performed prior to and during the settlement of agricultural land in C.3, namely, semi-detailed soils and land capability studies and an exploratory forest inventory of the entire Subregion, to be followed by detailed soils and forest surveys of colonization projects immediately prior to settlement.

For those areas selected as forest reserves on the basis of the land capability studies, the data from the exploratory inventory should be sufficient for determining the most feasible methods of managing these reserves. Designated forest zones may not occur as large or continuous tracts within the Subregion. This would diminish the feasibility of large commercial operations. Until the extent and distribution of the areas to be reserved in forest is determined, the justification does not exist for a more detailed inventory. Furthermore, the precise information derived from detailed forest inventories needed for planning logging and sawmill activities and negotiating the terms of concessions to private loggers, need not be obtained by a government-sponsored survey. First, the recommended exploratory inventory should permit, estimates of timber volumes sufficient in accuracy to interest private enterprise. Second, a concession could be negotiated which obligates the concessionaire to perform the detailed inventory, as is the policy in Mexico. Furthermore, if a tax on harvested timber is to be levied, this need not be calculated from the volume of standing timber, as determined by a detailed inventory, rather it could be based on the volume and type of timber removed from the forest, and recorded at the sawmill. These alternatives are recommended in lieu of a government financed detailed inventory, which would be expensive, and perhaps unnecessary.

If large areas are found to be suitable for continuous exploitation, however, official control should be exerted to assure that logging practices do not diminish forest productivity. Permanent management plots should be established in representative areas in order to observe the best methods to be followed for achieving maximum sustained yield. Forest administration policy could be accordingly formulated and enforced.

4. Subregion C.4

The settlement potential and problems to development of Subregion C.4 are somewhat similar to those of C.2, however there is slightly more rural population and agricultural potential is lower due to the need for supplementary irrigation to achieve full productivity. It is nevertheless considered that the land resources could accommodate more rural families, even without irrigation, and that development could have what is essentially a colonization orientation.

Area and population

C.4 is the smallest area in the Colonization Development Region with 85,250 hectares. Rural population is dense in the Mocache and Quevedo areas (see demarcated zones on the Development Regions map), but outside these zones the average ratio is 30 persons per square kilometer or about 16 hectares per five-member family.

Climate and resources

Yearly rainfall averages between 2,000 and 2,5000 mm. and irrigation is desirable during at least four months. The fertile volcanic soils of the Pichilingue association occur throughout the Subregion. An estimated 25,000 hectares of land is located south of Quevedo, which could be irrigated with water diverted from the Vinces River.

Development

While development could be viewed in terms of intensification of agricultural production, this area is judged to hold possibilities for further settlement, especially if projects for supplemental irrigation prove feasible. Such projects, considered to be costly for this area, may be just as economical as projects in irrigable areas to the south which have fewer limitations to irrigation but also less fertile soils. The soils of Subregion C.4 have high potential productivity, owing in part to the reduced possibilities of fertility-loss through leaching in comparison with the same soils in the more humid northern sectors of the Colonization Development Region. These considerations pertinent to the development of irrigated agriculture must be viewed in context with the over-all economics of the Guayas Basin, including factors related to the export of cash crops such as bananas, whose harvest season could be changed by practicing irrigation. The economic benefits of increasing the number of annual harvests of certain food staples through irrigation should also be analyzed.

Suggested studies

To determine the most effective means of developing and further settling this Subregion, information must be obtained on soils, land capability and land use, for which detailed mapping is recommended. Detailed property identification studies must also be undertaken to more accurately determine the settlement capacity of the area and the most suitable land tenure pattern for colonization. It is further recommended that surface water be studied and that the possibility of flood control dams, reservoirs and drainage diversion be investigated. Wells should be drilled to determine the existence, quality and quantity of ground water which might be utilized if irrigation with surface water appears too costly. These data should permit a more accurate evaluation of the irrigation and other developmental possibilities as a point of departure for economic planning for the Subregion.

5. Subregion C.5

This Subregion is the largest of the colonization Subregions but its settlement capacity is somewhat limited by reduced rainfall and the lower capability of its soils. Considerable areas which still remain forested, however, could perhaps be colonized.

Area and population

On the 206,125 hectares in C.5, 37,100 rural inhabitants are settled, principally along the tributaries of the Daule River. Rural man-land ratio is 20 persons per square kilometer. High densities of rural population are found in the vicinity of Balzar and Pichincha and along portions of the all-weather road to Quevedo.

Climate and resources

C.5 is the center of a transition zone between Tropical Wet and Tropical Dry climates. Rainfall ranges from 2,000 mm. per year in the north to 1,500 mm. per year in the south. Irrigation is definitely required for year round crop production in the south. The soils of the area are the clay loams of the Balzar Association, which are less fertile than the Pichilingue soils found in the C.1, C.2 and C.4 Subregions. Approximately 63,000 hectares are still in forest, which has been heavily exploited for balsa and other timbers; 53,000 hectares of forest are located in the north and another block of 10,000 hectares is found to the west of Mocache and east of the all-weather road to Quevedo. The forested areas are largely uninhabited. There do not appear to exist any significantly large tracts of irrigable terrain in this Subregion. It also appears that the only rivers with a substantial dry season streamflow are the Daule and its tributary, the Congo River. The watersheds of other lesser streams to the south experience a marked dry season and their flow diminishes greatly during the dry months. The possibility of irrigation in selected areas in C.5 should not be ruled out, however.

Development

A certain degree of settlement is judged possible in this sub-region, particularly if lands still in forest are found to have agricultural capabilities. Other areas not in forest are sparsely populated and could be settled if it is found that they have good soils capabilities. However, the same characteristics that have relegated this Subregion to a relatively low priority for colonization development also make it impossible to confidently state the approach and types of projects needed for development.

It is nevertheless apparent that there is a northward movement of agricultural settlers along the Daule River. As this zone has generally poor soils, indiscriminate land clearing and shifting cultivation should be discouraged. The permanent deterioration of the soils due to these practices could result in the formation of a hollow frontier, as colonists push farther to the north leaving behind them worn out, unproductive soils. Land hungry colonists in these zones should be encouraged to settle on the more fertile soils in C.1 and C.2.

Suggested studies

Semi-detailed soils, land capability and land use studies are recommended. Detailed land tenure studies of permanently settled areas are needed and the extent of unsettled public lands should be ascertained. These studies should provide the data needed to better define the goals of agricultural development and land settlement in this Subregion.

6. Subregion C.6

Although this Subregion has relatively fertile soils, its high rainfall and generally steep terrain constitute serious problems for agricultural development. While agriculture is limited, interesting possibilities exist for forest and minerals exploitation and the development of hydroelectric power.

Area and population

C.6 has a total area of 109,500 hectares with an average rural population density of 13 persons per square kilometer. Its 14,900 inhabitants are located chiefly in the vicinity of the town of Maná and along the all-weather road from Quevedo to Quito. The remainder of the Subregion is virtually unpopulated, probably due to the fact that there are no roads.

Climate and resources

Yearly rainfall averages 3,000 mm. and temperatures range from subtropical in the north to tropical in the south. The fertile volcanic soils of the Maná Association occur throughout the Subregion. In the northern sector a total of 49,000 hectares of low mountain forest are found, with timber volumes estimated at 20,000 board feet per hectare. South of Maná approximately 30,000 hectares of deciduous broadleaf forest are growing. The saleable timbers have probably been removed already and this block of forested land appears to be undergoing settlement along its peripheries. Cacao and coffee are grown in settled areas and shifting cultivation is reportedly practiced.

Good sites for hydroelectric power plants can be found on the numerous streams descending the humid slopes. The region holds good potential for the exploitation of metallic ores, as it is highly mineralized in places. Mines and mineral occurences are presently located along the principal road routes, that is, near Santo Domingo de los Colorados and Maná. Prospecting activities will undoubtedly uncover more mineral deposits in less accessible areas.

Development

The variety of resources found in C.6 presents interesting possibilities for development, and the exploitation of its water, timber and mineral resources could be integrated into the over-all development plans for the Colonization Development Region and help to diversify its agricultural economy. The C.6 area is likely to attract spontaneous settlers who do not participate in official colonization or forest exploitation projects. While such spontaneous settlement does not appear imminent, its probability is high as soon as the better lands are settled. Moreover, forest exploitation activities in this zone are likely to be stimulated if a sawmill industry in the Quevedo or Santo Domingo de los Colorados areas is established. Official measures should thus be taken to assure the rational exploitation of the soils and timbers of the Subregion. Both of these resources could rapidly deteriorate under destructive logging and agricultural practices, causing problems of erosion, land slides and flooding. A good measure of official guidance should therefore be exerted in order to prevent these undesirable results.

Adequate vegetative cover should be maintained on steeper slopes and over soils with high erosion danger. Forest reserves may have to be established in such areas, and in small watersheds whose rivers will be used for generating hydroelectric power, the vegetation should be managed accordingly. The forests can be exploited nevertheless, since regeneration is rapid in the ecologic conditions which prevail in C.6. Good possibilities exist for achieving high timber production on the deeper volcanic soils, however the rough terrain constitutes a disadvantage to logging operations.

Over the less steeply sloping terrain various tree crops could be cultivated, however areas with agricultural soils are likely to be small and isolated by ridges and streams. The high cost of constructing and maintaining feeder roads in this high rainfall area, in order to make agricultural development possible, is an important factor to be weighed against the anticipated returns. These costs are pertinent to any consideration of timber and mineral exploitation as well.

Careful study is required in order to arrive at the most appropriate ways of effectively exploiting the resources found in C.6. While the Subregion has possibilities for a diversified economy, its geographical location with respect to the rest of the Colonization Development Region and the economic factors pertaining to construction and location of road routes indicate that the best approach is that of developing numerous small projects (hydroelectric sites, reduced scale logging operations, several small colonization projects on better soils, and mining exploitations) which would supplement the over-all development of the contiguous colonization areas to the west.

Suggested studies

As Subregion C.6 will probably be assigned a lower priority in programming the development of the Colonization Development Region, the main concern for the present is to obtain adequate information on over-all soils and land capability characteristics and land use for the purposes of ascertaining the type and degree of control needed to protect forest and soils resources from damaging exploitation. Mapping of this information at a semi-detailed intensity is judged to be sufficient for these needs. These maps will also enable fairly accurate estimates of hydroelectric and forest potentials as well as provide information important to the routing of roads. At a later date photo geologic and geochemical surveys should be initiated to explore the mineral resources of the area.

CHAPTER V

A Recommended Program of Investigations for the Guayas River Basin

The program of investigations for the Guayas River Basin that follows has been formulated on the basis of the findings of the reconnaissance survey of the Basin described in the preceding chapters. In summary, the OAS survey team determined that the natural resource wealth of the Guayas Basin centers around its soils and water resources, and to a lesser degree its forest resources. Major development efforts will thus be concentrated in irrigated and nonirrigated agriculture and complementary activities in forest exploitation. Favorable combinations of climate, soils, water, forests and population density in selected locales indicate that intensive efforts can be directed at promoting development in specific areas with the assurance that development capital will yield high returns in a short time. Outside of these very high potential areas, varying degrees of limitations to development potential exist, which although not insurmountable, will require further preinvestment studies before feasibility investigations for project preparation can be undertaken. The guidelines for the development of the Guayas Basin presented in the previous chapter underlies the types and intensities of investigations and mapping, as well as the priorities in programming data collection, that are herewith presented, and which are intended to expedite the initiation of development projects.

Objectives

The general objectives of the recommended program of investigations are:

(1) to provide within the shortest time possible information useful for project planning and financing in selected regions with high development potentials;

(2) to define with greater precision the limitations of regions with lesser potentials so as to evaluate the justification of higher development costs;

(3) to provide basic data of sufficient detail and scope to be useful in planning and implementing programs for the development of the entire Guayas River Basin; and

(4) to train Ecuadorian personnel in the technical and administrative fields needed to carry out further investigation and to plan and implement development in the Guayas Basin.

Within two of the major Development Regions, Agricultural Intensification and Colonization, the subregions with the highest potentials for development will be investigated so as to furnish data for the planning and justification of irrigation and colonization projects. For the Forestry Development Region, surveys are planned which will lead to the formulation of forest management policies and plans for sustained-yield logging. In addition, the entire Basin will be surveyed in greater detail in terms of land use, land tenure and land capabilities to provide a point of departure for Basin-wide planning efforts and to furnish a technical base for formulating technical assistance and credit programs designed to increase production and promote better land use and conservation.

The basic orientation of the recommended program of investigations is toward planned development. Thus, the different components of the program have been formulated in terms of development planning needs and are justifiable on that basis. In addition, the necessity to obtain international financing for development implementation has been anticipated, and the investigations that are recommended have been conceived so as to satisfy the requirements for data needed to formulate development loan proposals. With regard to study methods, the unique aspects of tropical ecology and land use have been kept in mind in the specifications which are presented below concerning different kinds of surveys.

The Program, Schedules and Costs of the Investigations

The development regions and subregions discussed in the foregoing chapter have been employed to determine the types and intensities of studies and the areas to be covered by them. Subregions have been grouped, on the basis of common study needs or similar development possibilities, to constitute Program Areas, of which there are five, each covering a part of the Guayas Basin, and a sixth which consists of the entire Basin.1/ For each Program Area a plan of studies has been formulated which focuses on specific development projects or on specific problems which presently limit development.

In the description of the work components, a distinction is made between engineering and inventory services, both of which are regarded as professional work. Engineering services refer to work expended in the production of designs and feasibility determinations, and are expressed in terms of personnel needs. Inventory services refer to that which produces different types of maps depicting basic natural resource and other data, and are expressed in terms of the types of mapping required rather than personnel needs, although the personnel needs are included in the over-all estimates summarized in cost schedules 1 through 3 in Appendix D. This distinction between engineering and inventory services is made because of the difference in the work product and to help clarify the types and quantities of work needed to arrive at a more ready comprehension of time and costs required to accomplish the various work components in the different Program Areas. A further consideration is that a basic prerequisite to the work described below is the securing of 1:20,000 aerial photography of the Program Areas and the construction of mosaics at the scale of 1:20,000. The work schedule and over-all cost estimates for the investigation programs are summarized in Tables 7 and 8.

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1. See Figure 10, "Program Areas." The heavy black lines and Roman numerals define the Program Areas and their different components.

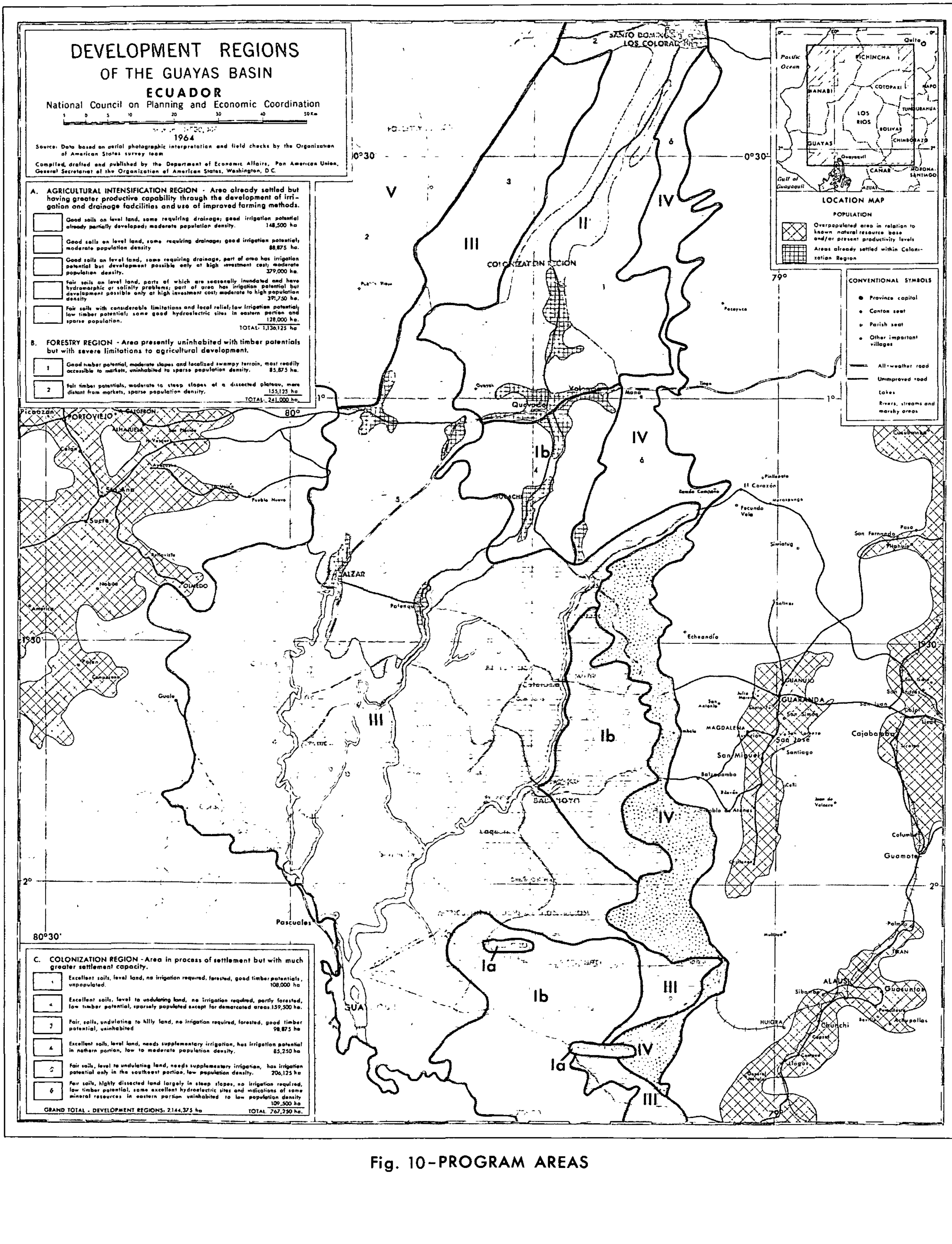
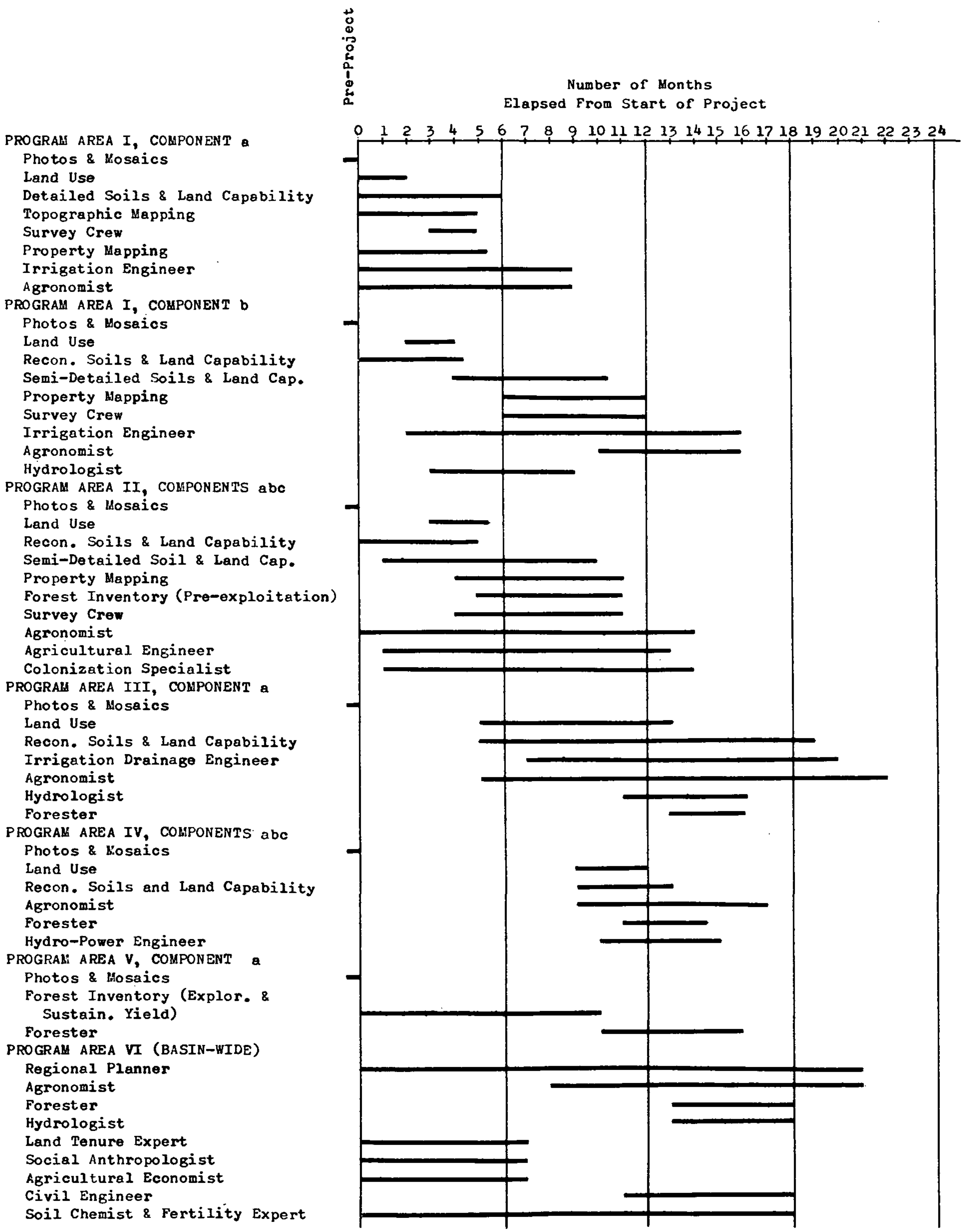


Fig. 10-PROGRAM AREAS

Table 7

SCHEDULE OF PROPOSED PROGRAM



N. B. Lines indicate duration of activity. The manpower applied to any activity at any time is not indicated.

Table 8

COST ESTIMATE OF PROPOSED PROGRAM

(generally follows AID cost-plus-fixed-fee form)

Item		From Schedule[1]	Man-Months	Total Amount	
1	Foreign Professionals	2	294	$294,000	
2	Overseas differential 15%			44,100	
3	Counterpart Ecuadorian Professionals	2	283	93,390*	
4	Other Personnel Requirements	3		74,600*	
5	Overhead 60% on Items 1, 3 and 4			277,114	
6	Home Office (back up salaries) (none anticipated in this estimate)			-	
7	Home Office overhead (none antic. in this est.)			—	
8	Fixed Fee 6% (on all but contingency, Item 16)			69,577	
9	Sub-total Items 1 through 8				$ 852,781
	Cost per man-months (includes Items 1 through 8)				
	Foreign Professionals $1,900.00				
	Ecuadorian Professionals 577.50				
	Ecuadorian Support 146.30				
10	Sub-contracts	4		86,433	
	Topographic mapping				
	Mosaic compilation				
	Drilling				
11	Travel, Per Diem, Housing Allowance and Shipping household effects	5		137,768**	
12	Vehicle and vehicle operation costs	6		73,320**	
13	Equipment other than vehicles	7		30,500**	
14	Other direct costs	8		48,400**	
15	Sub-total Items 10 through 14				376,421
16	Contingency (6% on all but fee, Item 8)				69,577**
17	Total Cost in U.S. Dollars				$1,298,779***

* Can be paid in Ecuadorian Currency.

** Can be paid in part in Ecuadorian Currency.

*** Can be paid $969,014 in U.S. Currency and $329,765 in Ecuadorian Currency (includes 1/2 of contingency in Ecuadorian Currency)

1. Schedules 2-8 appear in Appendix D, "Supporting Cost Schedules."

1. <u>Program Area I</u>

This Program Area consists of development subregions A.1, A.2 and C.4, representing a total area of 3,216 square kilometers. The excellent soils, terrain conditions and available ground and surface water which characterize the subregions in Program Area I justify immediate and intensive studies for developing irrigated agriculture. Where irrigation is already partially developed, it is judged that further development can be accomplished rapidly through improvements in existing irrigation works. The components of work in Program Area I are set forth below.

<u>Component I-a</u>: Studies and designs for improvement of existing irrigation systems and irrigated agriculture in the Manuel J. Calle and Milagro irrigation projects. These will include a review of existing canals and distribution networks to determine the extent and cost of additional construction needed, and to design the same; the design of distribution networks to individual water users; the formulation of a plan for central control and management of water use; plans for establishing experimental plots on representative soils and for different crop types; and the determination of crop, soils and water management practices which will lead to maximum sustained production.

(1) Engineering services: Two foreign experts, one irrigation engineer and one agronomist, each for five months, and two Ecuadorian counterpart technicians as well as an Ecuadorian survey crew will be required for three months.

(2) Inventory services: Property mapping: 9,000 parcels to be mapped in selected areas in Component I-a, as well as Component I-b, described below; land use mapping and detailed mapping of soils and land capability over approximately 260 square kilometers total; and 1:4,000 topographic maps of approximately 105 square kilometers (Milagro irrigation area) with 2 meter contour intervals.

<u>Component I-b</u>: Studies of areas without irrigation to select and rate potential irrigation project sites and determine their feasibility. Included will be feasibility studies for three potential irrigation projects, with either ground or surface water, which will provide the information required to formulate a development loan proposal for international financing.

(1) Engineering services: One Ecuadorian and one foreign irrigation engineer, each for 10 months: one Ecuadorian and one foreign hydrologist, each for five months; one Ecuadorian agronomist for six months and one foreign agronomist for six months; and a survey party of three Ecuadorians for six months.

(2) Inventory services: Land use mapping, 3,120 square kilometers; reconnaissance soils and land capability mapping, 3.120 square kilometers; semi-detailed soils and land capability mapping, 1,350 square kilometers; and property mapping specified in the description of Component I-a. Approximately 2,000 feet of exploratory drilling for groundwater will also be needed.

2. Program Area II

Program Area II consists of development subregions C.1 and C.2 within the Colonization Development Region, representing a total area of 2,610 square kilometers. From the standpoint of immediate development, this is the most promising area in the entire Basin, principally because development through planned colonization will require a minimum of engineering works, and additional studies in support of development plans can be accomplished rapidly. There are three work components for Area II.

Component II-a: Identification, selection and feasibility determination of areas to be colonized.

Component II-b: Preparation of a detailed plan for one high priority colonization project, which will include farm layouts, and plans for land and crop management, marketing, housing and road construction, pilot farms, and other items required for a loan proposal for international financing.

Component II-c: Preparation of feasibility studies for three other colonization areas in accordance with the informational needs indicated in Appendix E and including any other data considered to be pertinent and suitable for justifying expenditures entailed in colonization project development.

(1) Engineering services: For all three work components; one Ecuadorian and one foreign agronomist, each for five and one-half months; one Ecuadorian and one foreign agricultural engineer, each for ten months; one foreign expert for consultation on colonization and with experience in Latin American Tropics, for ten months; and a survey crew of three Ecuadorians for six months.

(2) Inventory services. For all three work components: land use mapping, 2,610 square kilometers; reconnaissance soils and land capability mapping, 2,610 square kilometers; semi-detailed soils and land capability mapping, 1,350 square kilometers; pre-exploitation forest inventory, 1,070 square kilometers; cadastre of approximately 4,000 parcels.

3. Program Area III

Program Area III consists of development subregions A.3, A.4, C.3 and C.5, and represents a total area of approximately 10,780 square kilometers. Although the OAS survey team found that subregions in Program Area III have certain limitations which diminish development potential, selected areas or types of development are judged to prove feasible upon further study. The task in Program Area III is to locate and evaluate those areas.

Component III-a: Identification, selection and evaluation of feasibility of areas suitable for drainage projects, irrigation with either ground or surface water (or a combination of irrigation and drainage), colonization projects not requiring either drainage or irrigation measures, and a very general forest management plan for subregion C.3 that is complementary to the consideration of colonization possibilities in that subregion.

(1) Engineering services: One Ecuadorian and one foreign irrigation engineer, each for 12 months; one foreign drainage and irrigation engineer for 12 months; one Ecuadorian and one foreign hydrologist, each for five months; one Ecuadorian and one foreign agronomist, each for 10 months; one Ecuadorian and one foreign forester, each for 3-1/2 months.

(2) Inventory services: Land use mapping and reconnaissance soils and land capability mapping of 10,780 square kilometers; approximately 2,000 feet of exploratory drilling for groundwater.

4. Program Area IV

Program Area IV consists of development subregions C.6 and A.5, and has a total area of approximately 2,590 square kilometers. This program area is characterized by steep slopes and high rainfall, particularly in C.6, and development possibilities include hydroelectric power projects, forest exploitation and perennial crop cultivation. Agricultural and logging activities will have to be controlled commensurate with the watershed function of the program area and the dictates of conservation.

Component IV-a: Identification, selection and rating in terms of feasibility of sites with potential for hydroelectric power production.

Component IV-b: Identification, selection and feasibility rating of areas suitable for agricultural production.

Component IV-c: Development of watershed management plans, including establishment of forest management and soil conservation policies and plans.

(1) Engineering services: One foreign hydroelectric engineer, four months; one Ecuadorian and one foreign agronomist, each for six months; and one foreign forester and specialist in watershed management and an Ecuadorian counterpart, each for two months.

(2) Inventory services: Land use mapping and reconnaissance soils and land capability mapping of the entire Program Area (2,590 square kilometers).

5. Program Area V

Program Area V consists of development subregions B.1 and B.2, and covers a total area of approximately 2,420 square kilometers. The development potential of this program area lies in its forest resources, which could be exploited as a complementary economic activity to the colonization undertaken to the east in the Colonization Development Region. There is only one work component for this program area.

Component V-a: Preparation of a sustained yield forest management plan for the forest resources on the Program Area and the formulation of official policy concerned with forest exploitation.

(1) Engineering services: One foreign and one Ecuadorian forester, each for six months.

(2) Inventory services: Exploratory forest inventory of the entire program area (2,420 square kilometers) followed by a sustained yield management type inventory of approximately 1,200 square kilometers.

6. Program Area VI

Program Area VI consists of 21,780 square kilometers within the Guayas Basin which correspond to the areas covered by the three major Development Regions. The first five Program Areas fall within Program Area VI, however the investigations of these are concerned with specific development aspects within selected regions. The reason for treating the entire area as a single geographic study unit is to orient investigations in terms of regional problems that affect the integrated economic development of the Guayas Basin. The studies to be undertaken under the title of Program Area VI thus have the purpose of accomplishing the third objective stated at the outset of this chapter.

The investigations proposed for Program Area VI fall into three general categories according to the objectives and types of data to be collected:

Investigations complementary to those undertaken in Program Areas I-V

These studies will include farm management and agricultural land use practices studies of the major types of agricultural enterprises operating at different managerial and technological levels and in different ecologic conditions. For representative soils in the different program areas attempts will be made to arrive at approximate productivity ratings. This information will then be used in the formulation of land capability ratings and in the determination of necessary modifications in land use patterns and the types of technical assistance needed to achieve better land use. In addition, the anticipated economic impact of development projects in colonization and irrigation will be determined.

Investigations for the formulation of soil, water and forest conservation policies

These studies will include dterminations of the influence of land capabilities on over-all plans for regulating the exploitation and use of soils, water and forest resources and will constitute for the most part a compilation and interpretation of data collected in Program Areas I - V in terms of necessary official controls in resource use.

Investigations for regional economic development planning

The following studies or evaluations must be undertaken and interpreted in terms of over-all regional planning and programming: land taxation policy and practices, projected transportation needs, public health facilities and projected needs, education facilities and projected needs, measures needed for further commercialization of agricultural production.

For all of the above investigations it is considered that a great deal of existing published and unpublished data can be compiled and interpreted in terms of Program Area VI. Some field work will be necessary in order to collect data concerning productivity of different farm types in different ecologic regions.

Professional services required. Foreign expert in regional planning and Ecuadorian counterpart, each for 12 months; one Ecuadorian and one foreign agricultural economist, each for six months; one Ecuadorian and one foreign civil engineer, each for six months; one foreign expert in land tenure and land taxation and Ecuadorian counterpart, each for six months; one Ecuadorian and one foreign forester, each for 4-1/2 months; one Ecuadorian and one foreign agronomist, each for seven months; one Ecuadorian and one foreign hydrologist, each for five months; one Ecuadorian and one foreign soils chemist, each for 18 months; and one foreign social anthropologist and Ecuadorian counterpart, each for six months. With the exception of the social anthropologist, all of the other foreign experts are the same persons who will take part in earlier studies for the Program Areas I through V.

General Specifications for Inventory and Feasibility Studies

Following in the order indicated are the general specifications for performance of the various inventory type studies and guidelines for colonization feasibility studies required in the program.

1. High intensity reconnaissance soil survey
2. Semidetailed soil survey
3. Detailed soil (land classification) survey
4. Land use survey
5. Reconnaissance land capability survey
6. Semi-detailed land capability survey
7. Detailed land capability survey
8. Pre-exploitation forest survey
9. Exploratory and sustained yield management forest inventory
10. Property mapping

11. Topographic mapping (see Schedule 4, Appendix D)

12. Aerial photographic mosaics (see Schedule 4, Appendix D)

13. Outline of colonization feasibility study requirements

1.	Type of study:	High intensity reconnaissance soil survey
	Purpose:	To refine and re-delineate boundaries of mapping units of the existing reconnaissance soil survey, and to determine the most promising areas for agricultural development in terms of colonization and irrigation.
	Area:	The high intensity reconnaissance soil survey will be conducted throughout Program Areas I-b, II, III and IV, a total of 19,100 Km^2.
	General specifications, special considerations, and procedures:	The high intensity reconnaissance soil survey should be conducted by means of photointerpretation of the 1:20,000 scale photography, when available, and by examination of the soils in the field at moderate to wide intervals, particularly in areas where delineation of contiguous mapping units cannot be readily made by means of photointerpretation. Cartographic units should be the soil associations established in the existing reconnaissance soil survey, and procedures should follow, to the extent possible, those recommended by the USDA Handbook 18, "Soil Survey Manual," for comparable studies.
	Delivery items:	The mapping should be presented either along with the land capability or land use mapping of the same areas on the 1:20,000 scale base aerial photomosaic, screened on cronaflex, or alone on a reduced scale (suitable to the density of detail) screened cronaflex of the base mosaic. A written report should accompany the map.
2.	Type of study:	Semi-detailed soil survey
	Purpose:	To determine those areas where agricultural development, colonization and irrigation projects are technically feasible.
	Area:	The semi-detailed soil survey will be conducted in the areas indicated by the high intensity reconnaissance soil survey as most promising for agricultural development in Program Areas I-b and II. A total of 2,700 Km^2 about evenly divided between the two program areas is to be accomplished.

General specifications, special considerations, and procedures:	The semi-detailed soil survey will be conducted by detailed photointerpretation of the 1:20,000 scale photography, when available, and examination of the soils in the field to an extent which will permit an evaluation of general levels of fertility and major soil management problems. Cartographic units should be soil series and significant soil types and phases when these are relevant for determination of feasibility of agricultural development or irrigation projects. Procedures should follow, to the extent possible, those recommended by the USDA for the colonization areas and those of the U.S. Bureau of Reclamation for irrigation areas.
Delivery items:	The mapping should be presented on the 1:20,000 scale base aerial photo mosaics, screened on cronaflex, and accompanied by a report.
3. Type of study:	Detailed soil (land classification) survey
Purpose:	To determine the most efficient use of irrigation and other soil management practices in areas undergoing irrigation development.
Area:	The high intensity detailed soil survey will be conducted in areas already programmed for irrigation, namely Program Area I-a, a total of 260 Km^2 to be mapped.
General specifications, special considerations, and procedures:	The high intensity soil survey will be conducted by examination of the soil in detail at close intervals to determine differences significant to the determination of the most efficient use of irrigation and other management practices. Cartographic units should be land classes according to U.S. Bureau of Reclamation specifications for detailed surveys in irrigable areas and procedures should generally follow these specifications.
Delivery items:	The mapping should be presented on a screened cronaflex aerial photo mosaic base at a scale suitable to the detail presented, and accompanied by a written report.
4. Type of study:	Land use surveys
Purpose:	To identify and map existing land use patterns for a determination of the availability of unused land, and of the intensity and type of land use in settled areas, for developing colonization, irrigation and complementary land use development programs.
Areas:	Program Areas I, II, III, IV, and VI, a total of 19,360 Km^2.

General specifications, special considerations, and procedures:	The work will be performed by interpretation of 1:20,000 scale aerial photographs and field checks. Criteria for formulating cartographic units will depend upon the intensity of detail required in the various Program Area studies. For Program Areas I-b, II, III, and IV, a generalized or reconnaissance land use survey is required of agricultural and other land use, both commercial and subsistence cultivation, by major crops or other land use categories, permanency of crops, periodicity of cultivation and frequency of harvest, and use of irrigation, as well as a classification of vegetation in uncultivated areas by associations, and in areas of shifting cultivation, by degree of regeneration. Detailed land use surveys for Program Area I-a are needed and will entail crop type identification. The land use mapping of Program Area VI, the entire study area, will constitute a compilation at a reduced itensity of detail of the surveys described above, as well as the forest surveys presented below.
Delivery items:	Land use mapping should be presented on the 1:20,000 scale aerial photomosaic base, screened on cronaflex. An appropriate legend and written report should accompany the maps.
5. Type of study:	Reconnaissance land capability survey
Purpose:	To define major potential use of cartographic units established by high intensity reconnaissance soil survey and reconnaissance land use survey, as represented by maximum sustained productivity.
Area:	The reconnaissance land capability survey should be conducted in Program Areas I-b, II, III, and IV, a total of 19,100 Km^2.
General specifications, special considerations, and procedures:	The reconnaissance land capability maps should be compiled from the high intensity reconnaissance soil surveys, the reconnaissance land use survey and from pertinent data collected during the above-mentioned surveys and from local agronomists. Procedures should follow those of reliable established methods for land capability studies, but should make allowances to account for local conditions and to satisfy the informational needs of the various development programs.
Delivery items:	Reconnaissance land capability maps, which should be compiled at the same scale as the high intensity reconnaissance soil survey maps.
6. Type of study:	Semi-detailed land capability survey
Purpose:	To define major potential use based on maximum sustained productivity for selected colonization and irrigation areas under study.

	Area:	The semi-detailed land capability survey will be conducted in portions of Program Areas I-b and II, a total of 2,700 Km^2.
	General specifications, special considerations, and procedures:	The semi-detailed land capability survey should be compiled from the semi-detailed soil and land use surveys, and from data obtained from local agricultural experience and observations. Procedures should follow those used for the reconnaissance land capability survey, but carried to a higher degree of refinement and taking into consideration the informational needs of the colonization and irrigation programs.
	Delivery items:	The land capability mapping should be presented on the 1:20,000 scale aerial photomosaic base (screened on cronaflex) and accompanied by a written report.
7.	Type of study:	Detailed land capability survey
	Purpose:	To determine major potential use of irrigated areas as represented by maximum sustained productivity.
	Area:	The detailed land capability survey should be conducted in Program Area I-a and is equivalent to the detailed soil survey established for that area.
	General specifications, special considerations, and procedures:	The general specifications for the land capability survey have been stated under Detailed Soil (land classification) survey (No. 3 above).
8.	Type of study:	Pre-exploitation forest survey
	Purpose:	To provide a gross estimate of the volume of standing merchantable timber in areas which are destined for colonization in order to permit the planning of forest products extraction, marketing, and utilization.
	Area:	Program Area II, 1,070 Km^2.
	General specifications, special considerations, and procedures:	It is suggested that in the pre-exploitation survey local volume tables be constructed on the basis of 100% surveys of selected forest types determined by aerial photointerpretation and ground checks. The use of such tables obviates the time consuming procedure of height measurements during the course of ground sampling, which it is estimated can be at an intensity of one percent once the initial photointerpretation has been carried out.
	Delivery items:	The results of the inventory should be presented on a 1:20,000 scale aerial photographic mosaic base with the appropriate interpretations, tabulations, and analyses of the ground sampling presented in an accompanying report.

9. Type of study: Exploratory forest survey followed by a survey for sustained yield management

Purpose: To determine the presence and extent of commercial forests and to provide the information necessary for formulating a sustained yield management plan for areas of commercial forests, and for formulating over-all forest administration plans for both commercial and noncommercial forests.

Area: The exploratory survey will be conducted throughout Program Area V, an area of 2,420 Km^2. It is estimated that 1,200 Km^2 of this area may merit the sustained yield management inventory.

General specifications, special considerations, and procedures: It is suggested that the following procedure be employed: photointerpretation of the entire area to determine the extension, distribution and location of well drained sites with well developed forests. The results of this photo reconnaissance should then be analyzed with regard to accessibility factors and apparent volume of timber and presented to the appropriate Ecuadorian authorities in order to decide if the costs of the follow-up sustained yield type inventory are justified. For the sustained yield forest survey, it is suggested that the species and diameter classes to be inventoried be decided beforehand in accordance with economic considerations, that a local volume table be developed for the ground sampling, and that ground sampling intensity be on the order of three percent. In addition, management plots should be established in representative forest sub-types for long-term observations of regeneration rates.

Delivery items: A location map (the 1:20,000 photomosaic base) showing survey transects and other pertinent annotations accompanied by a technical report describing the methods and results of the inventories.

10. Type of study: Property mapping

Purpose: To provide information on property boundaries and ownership in the areas encompassed by development programs, including those for which feasibility studies will be conducted in support of agricultural development; also to provide information pertinent to land tenure studies and development of land taxation programs, particularly for irrigated lands.

Area: The property mapping will be undertaken in Program Area I-a and in those portions of I-b and II which will undergo feasibility studies. Approximately 9,000 parcels will be mapped in Program Areas I-a and I-b and 4,000 parcels in Program Area II.

General specifications, special considerations, and procedures:	Properties will be delineated and numbered individually on aerial photographic mosaics and measured on these by employing compensating polar planimeters. Identification of boundaries will be done by utilizing existing plans and survey descriptions on file in government offices and by observations of fences, streams, roads, field boundaries and other natural features which can be identified on aerial photographs and/or in the field.
Delivery items:	The delivery items should be the 1:20,000 aerial photographic mosaics, screened on cronaflex, depicting the identified boundaries and other pertinent annotations, and an accompanying list of land owners.
11. Type of study:	Topographic mapping (see Schedule 4, Appendix D)
12. Type of study:	Aerial photographic mosaics (see Schedule 4, Section F)
13. Type of study:	Outline for colonization feasibility study requirements

The document in Appendix E entitled "Suggested Outline for the Presentation of a Settlement Project" was extracted from a technical paper authored by the Inter-American Development Bank in June 1963, having the purpose of setting down the guidelines for project presentation in the different fields of agricultural development, for financing from the Social Progress Trust Fund. This part of the IDB paper demonstrates what are the informational requirements for colonization project preparation for international financing. It is suggested that the feasibility studies to be undertaken for selected colonization zones in Program Area II be designed so as to obtain the data needed for the presentation suggested by the Inter-American Development Bank, and that the one colonization project which is to be formulated for this Program Area adhere as faithfully as possible to the IDB outline. It may not be found necessary to provide a social justification for the colonization project, however, and in this case data need not be obtained for this aspect of project justification.

Training and Ancillary Advisory Activities

Two basic types of training activities are projected: in-service or on-the-job training, and special advisory services and formal training courses. The latter activities are considered as a separate and additional cost not budgeted in the present program but whose cost could be borne by international agencies engaged in these types of endeavor.

1. On-the-Job Training

On-the-job training will be provided through the working association of Ecuadorian and foreign specialists. It will be the task of the foreign specialist to insure that his counterpart acquires a knowledge of the principles and techniques utilized throughout the program work.

2. Other Advisory and Training Activities

The above elements of the project organization are inherent in and essential to the project and if not budgeted in the project cost, they must be provided for from Ecuadorian government funds. A number of additional training and advisory activities that would be valuable directly or indirectly to the pursuit of the project can probably be financed through existing assistance programs of various international agencies and financing for these ancillary projects should be so sought. These activities include:

(a) Consultation to the National Planning Board on management of the project and utilization of data in regional planning (2 man years, travel and allowances suggested).

(b) Special technical assistance to the Planning Board in matters related to the project (4 man months, travel and allowances suggested).

(c) Project development assistance by foreign experts to advise the consultant and the National Planning Board on modern approaches and procedures in certain technical aspects of the project, such as aerial photographic interpretation techniques for tropical soil classification and forest surveys (2 man years travel and allowances suggested).

(d) Fellowship program in the United States: two fellowships in soil classification; one in hydrology; one in forestry; and one in groundwater geology. Financing for these studies could perhaps be provided through the regular Fellowship Program of the OAS.

(e) Special training in Europe: a special course (8 months) in soil classification and photographic interpretation techniques for technicians of the Instituto de Colonización and the Departamento de Suelos of the Ministerio de Fomento; and a special course (8 months) in photo geology and geomorphology for technicians from the Departamento Nacional de Geología of the Ministerio de Fomento. It is suggested that these courses could be financed by the Extra-Continental Training Program of the OAS.

(f) Training courses in Ecuador: a six-week course in basic photointerpretation; and a four-week course in property boundary delineation. These courses could be undertaken as part of the Technical Cooperation Program of the OAS. Properly scheduled, these training and advisory activities would provide valuable support to the project.

Organization of the Program

1. Control of the Program

To accomplish a program as complex and at the same time as interrelated as the one which has been recommended will require a high degree of organization and central control. This control must emanate, furthermore, from the highest possible administrative level in keeping with the importance of the program and to provide the authority necessary for coordination of functions in many different parts of the Ecuadorean government. In light of these conditions and because of the essentially regional orientation of the over-all project, it is recommended that control of the project be placed in the hands of an executive director within the Junta Nacional de Planificación y Coordinación Económica. The executive director should be an Ecuadorean professional whose experience would command the respect of agencies and personnel with whom he would deal and whose prestige would insure access to the highest levels of government.

2. Advisory Groups

In order to facilitate the coordination and management of the project, it is further recommended that an advisory group to the executive director be created. The chairman of the advisory group would be the Director of the Junta Nacional de Planificación y Coordinación Económica and it would be made up of high level Ecuadorean officials from the various ministries participating in the project, as well as consultants and advisors invited at the discretion of the chairman. The advisory group should meet regularly at a time designated by the chairman.

3. Performance of the Work by a Contractor

In view of the fact that time is a critical factor in this project, and that local agencies in the fields of soils, forestry, land use, etc., have an extremely limited number of qualified technicians who could participate in the project, it is felt that the best approach to the conduct of the program would be for the Government of Ecuador to engage a reliable regional planning and/or consulting engineering firm or a similar type firm experienced in comparable programs. The consultant would perform all the technical and administrative tasks necessary to the performance of the program and be responsible to and report to the executive director as well as the financing institution. This arrangement would also provide the strong central control needed for proper integration of the various aspects of the program.

4. Coordination with other Agencies

There exists a parallelism between some of the activities of the proposed program and the responsibilities of the existing Ecuadorean agencies working in the fields of soils, forestry, irrigation, and colonization. Close coordination between the agencies and the development program must be achieved in order to have effective pursuit, continuation and maintenance of the development projects and other elements of development in the Guayas Basin that will be forthcoming from the proposed program. This coordination should be achieved at two levels: first, at the administrative level through the advisory committee to the executive director mentioned above; second, at the technical and operating level through counterpart Ecuadorian engineers attached to the consultant staff. The Ecuadorian professionals should be drawn from the agencies which are engaged in programs related to their specialization. Although each Ecuadorian professional will be on leave of absence from his agency to work on the consultant's staff, his responsibilities will include that of being the coordinating agent at the technical level between the project and his parent agency.

Aerial Photography and Mosaics

1. Aerial Photography

In order to provide the cartographic base for recommended studies and mapping of natural resources and the delineation of properties within the selected areas of the Guayas Basin, it is essential as stated in the program above, that large scale aerial photography be flown. Considering the various uses to be made of the photography, it appears that a scale of 1:20,000 is best suited to the needs. The area which has been recommended for aerial photography is shown on Figure 11.[2] It includes all of the project area defined previously with the exception of the area around Guayaquil. Photography has not been proposed for this area because medium-scale coverage (1:35,500) already exists for the area as shown on Figure 11. The total area recommended for photography within the Guayas Basin is 28,000 square kilometers, which is roughly 85 percent of the area of the Basin.

The proposed area is one of the most difficult in the world to photograph because of an almost constant low cloud base. Reports regarding flying weather in the area are conflicting, but it appears that the number of cloud-free days per year is extremely limited and their occurrence is somewhat unpredictable. While it is hoped that coverage of the recommended area might be accomplished in a year, it might take longer.

It is most important that the contract for flying be let with sufficient lead time to allow for completion or near completion of the flying prior to the date of initiation of the project. The lead time allowed should be about one year.

2. Mosaics

The mosaics (see schedule 4, Appendix D, for description) which will serve as the cartographic base for the project work should also be prepared prior to the initiation of the project.

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2. The recommendations regarding aerial photography were presented to the Government of Ecuador and USAID at the termination of the period of field work of the first OAS Mission in September 1963. The Government of Ecuador accepted the area delineated by the Mission as first priority for 1:20,000 photography, and in addition proposed that coverage be obtained of contiguous areas including most of the remainder of the Guayas Basin and other portions of the coastal region of the country. Figure 11 shows the total area recommended for photography in the Guayas Basin. The cost of the photography is to be paid for out of a Development Loan Fund (DLF) loan to the Government of Ecuador.

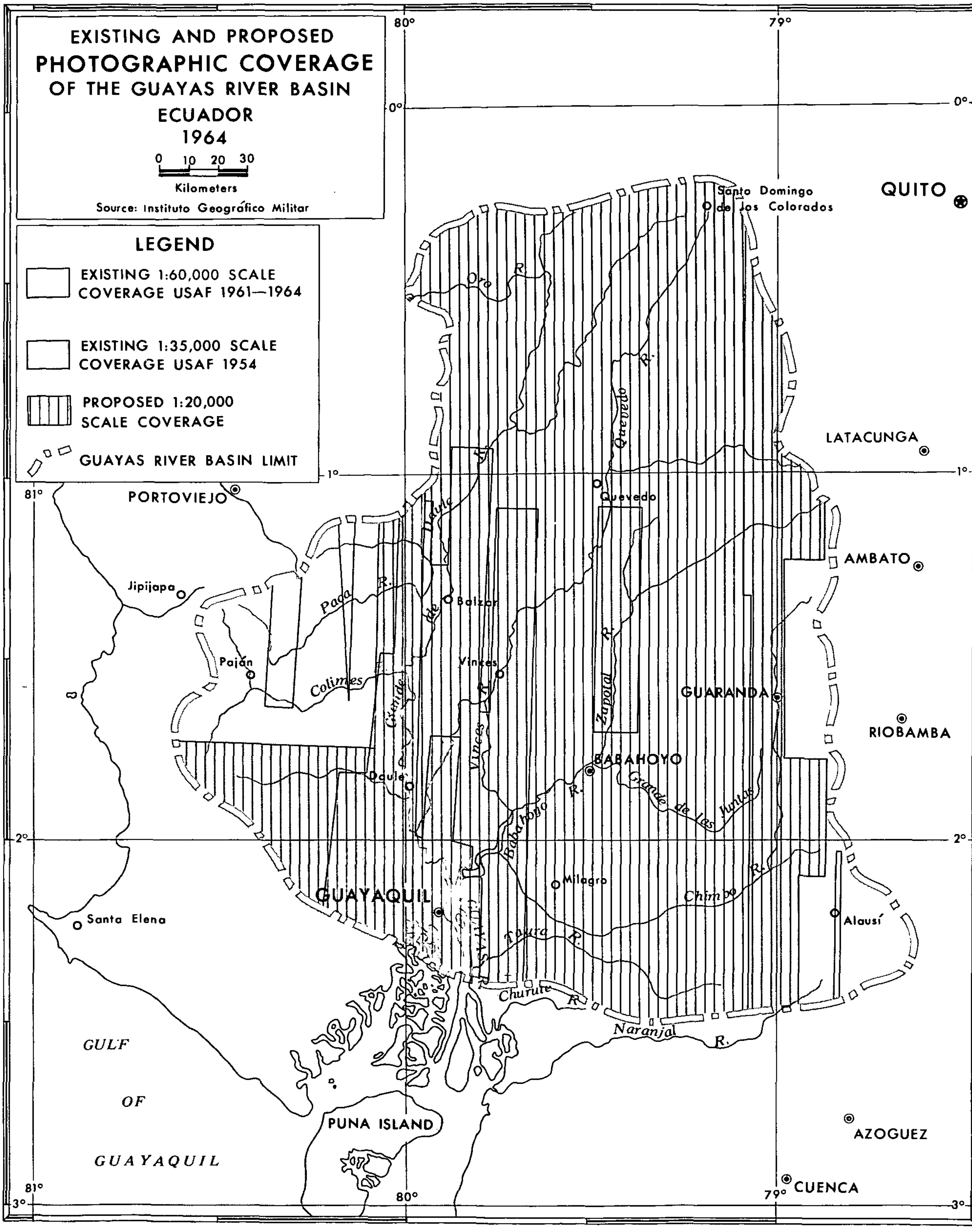

EXISTING AND PROPOSED
PHOTOGRAPHIC COVERAGE
OF THE GUAYAS RIVER BASIN
ECUADOR
1964
0 10 20 30
Kilometers
Source: Instituto Geográfico Militar
LEGEND
EXISTING 1:60,000 SCALE COVERAGE USAF 1961—1964
EXISTING 1:35,000 SCALE COVERAGE USAF 1954
PROPOSED 1:20,000 SCALE COVERAGE
GUAYAS RIVER BASIN LIMIT
Santo Domingo de los Colorados
QUITO
LATACUNGA
AMBATO
RIOBAMBA
GUARANDA
BABAHOYO
Quevedo
Balzar
Vinces
Daule
Milagro
GUAYAQUIL
Alausí
Santa Elena
PORTOVIEJO
Jipijapa
Paján
PUNA ISLAND
AZOGUEZ
CUENCA
GULF OF GUAYAQUIL
Oro R.
Quevedo R.
Daule R.
Paca R.
Colimes
Zapotal R.
Vinces R.
Babahoyo R.
Grande de las Juntas
Chimbo R.
Taura R.
Churute R.
Naranjal R.
80°
79°
81°
0°
1°
2°
3°

Fig.11

APPENDICES

APPENDIX A

Contract between the National Planning and Economic Coordination Board, an Agency of the Government of the Republic of Ecuador, and the Pan American Union of the Organization of American States.

THIS CONTRACT entered into the 28th day of June 1963, between the National Planning and Economic Coordination Board (hereinafter referred to as "Planning Board"), an agency of the Government of the Republic of Ecuador (hereinafter referred to as "GOE") who will appoint a contracting officer; and the Pan American Union of the Organization of American States (hereinafter referred to as "Contractor") whose address is 1725 "I" Street, N.W., Washington 6, D.C.

WITNESSETH THAT:

WHEREAS, this contract is part of the cooperative program being carried out in Ecuador between the GOE and the Government of the United States, represented by the Agency for International Development (hereinafter referred to as USAID) under the Alliance for Progress; and

WHEREAS, the Planning Board requires certain contractual services in connection with a resources survey of the Guayas River Basin with particular emphasis on identifying and describing those development projects which hold the best promise for economic results; and

WHEREAS, the Contractor represents that he is qualified by training, education and experience and he is willing to undertake the work and services set forth in Article I hereof,

NOW THEREFORE, the parties hereto agree as follows:

ARTICLE I - STATEMENT OF WORK

A. Duties

The Contractor shall perform the following:

1. Within the potentially rich but so far underdeveloped region known as the Guayas River Basin, the Contractor will carry out field investigations, will study, interpret and evaluate the existing aerial photography of the region which is available in Ecuador and will compile data and other available information sufficient to permit the classification of subregions or zones according to criteria of natural resource and economic potential.

   Reconnaissance mapping and other survey and research work will be carried out with respect to the entire river basin, but only that portion of the basin which is presently covered by aerial photography (roughly 60 percent) can be mapped and studied with reasonable precision. Reconnaissance study and mapping in the remaining portions of the basin must be based upon existing generalized maps and data supplemented by such field work as will be possible within a two-month period.

A final product of the resource study phase of the contract will be the publication of a series of at least five reconnaissance soils, geomorphology, geology, vegetation, ecology, present land use, land capability and population distribution.

2. Based upon the foregoing evaluation of the present and potential resources of the Guayas River Basin, the Contractor will:

   a. Identify areas suitable for further development and the physical problems which curtail such development.

   b. Prepare the terms of reference for loan applications for investigations of natural resources (using rapid modern aerial methods).

   Such investigations are required for determining feasibility of resource development projects and refining the basis for future project selection and priority determination. Included within the terms of reference to be provided by the Contractor will be detailed cost estimates and technical specifications in order to facilitate the preparation of the loan applications.

3. In order to accelerate the initiation of specific projects in the Guayas Basin, the Contractor will undertake the preparation of the terms of reference for certain priority projects of natural resource development in the Guayas River Basin. These are the irrigation projects of Milagro y Manuel J. Calle, or any other project in substitution of the aforementioned which the parties agree upon.

B. Staffing

To assure success of the project the Contractor agrees to supply personnel, trained and experienced in all fields necessary to carry out the work required by this contract including, but not limited to personnel trained and experienced in the fields of geography, agricultural economics, soils analysis, forestry, geology and cartography. Home office research and analysis services will also be provided.

Anticipated positions, which may be varied by agreement in writing between the Contractor and the Contract Officer, with estimated man-week requirement for each are as follows:

Service	Man-Week
Project Coordinator	2-1/2
Project Leader (geographer)	7
Agricultural Economist	8-1/2
Irrigation Engineer	8-1/2
Soils Specialist	8-1/2

Service	Man-Week
Forester	8-1/2
Photo Geologist	8-1/2
Cartographer	8-1/2
Home Office Cartographer	17

C. Reports

The Contractor will keep the GOE informed as to the progress of the implementation of this contract, and will prepare such progress reports as may be requested. The Contractor is to prepare a final report containing findings and recommendations as to the future development of the Guayas Basin, including identification and discussion of specific areas and their physical problems of resource development. The selected areas will be those deemed appropriate for eventual detailed feasibility studies leading to possible loan applications, domestic or foreign investment, or other means of financing such projects.

D. PAN AMERICAN UNION (Contractor) Additional Contribution

In addition to the above, the Contractor will further cooperate in the project by providing at no cost to the GOE the salary for services of the project coordinator, for 14 days in the field and an estimated 30 days in Washington; the salary of an agricultural economist for 60 days in the field; compilation and cartographic laboratory equipment and office space and facilities in Washington; and salaries of cartographic personnel engaged in the supervision and execution of final map work and publication of the reports.

ARTICLE II - ESTIMATES, LIMITATIONS ON FUNDS AND FIXED FEES

A. Estimate of Cost

The estimated cost of the work under this contract is US$24,000.

B. Fixed Fee

The Contractor's fixed fee is none.

C. Revised Estimates of Cost

The contracting officer may by written notice to the Contractor revise the estimate of the cost of the work and from time to time further revise any revised estimate of cost after obtaining the concurrence of AID.

D. Time of Completion

The field work and report writing to be performed under this contract shall be completed by the Contractor within four months from the date of the contract or as soon thereafter as possible, depending on the exigencies of of the work, as may be agreed upon by the parties in writing. The preparation and publication of maps which are included within the scope of the work shall be completed within six months from the date of the contract unless otherwise agreed upon by the parties in writing.

E. Obligated Funds and Limit on Total Payments

There is presently obligated for commitment under this contract the amount of US$24,000 which may be utilized for U.S. dollar cost as set forth in Article III, hereinafter called "obligated funds." Additional U.S. dollar sums may be allocated to this contract only as provided under Article II, (C) above.

ARTICLE III - COSTS REIMBURSABLE AND LOGISTIC SUPPORT TO CONTRACTOR

A. U.S. Dollar Costs

The U.S. dollar costs allowable under the contract shall be limited to reasonable and necessary costs determined in accordance with the provisions of "Appendix A, Cost Provisions," attached hereto and made a part hereof except as such provisions are modified, herein next below:

1. Salaries paid to technicians during the period of the contract are not to exceed the following limitations:

Project Leader	$ 2,000
Soils Specialist	2,400
Forester	1,600
Photo Geologist	2,400
Cartographer	600
Home Office Cartographer	2,500
Total Salaries	$11,500

2. The workweek for each employee assigned by the Contractor pursuant hereto shall be a minimum of 40 hours. No additional compensation is authorized under the contract for any amount of overtime that may be performed in carrying out the official duties herein prescribed.

3. No additional compensation is authorized for overseas differential.

4. The cost of one-round trip transportation by air between Washington, D.C. and Quito, Ecuador, for the Contractor's personnel authorized under this contract in accordance with paragraph 3 of Appendix A hereof. Reimbursement to the Contractor for such travel and per diem of his employees shall be made in accordance with the provisions of the Standardized Travel Regulations of the United States Government, as from time to time amended. Estimated cost: $3,200.

5. Miscellaneous expenses, as set forth under Section I, Paragraph 7, Appendix A hereof, and including reproduction and compilation costs, publication of maps and reports, and other home office and field support costs connected with the final successful accomplishment of the scope of work described herein shall not exceed $4,500 without prior written authorization of the contractor officer.

6. Per diem rates, in lieu of quarters allowance shall be paid to the Contractor's field staff members while performing services in Ecuador in accordance with the rates prescribed in the Standardized Travel Regulations (Government and Civilian Foreign Areas) as from time to time amended. Estimated cost: $4,800.

7. As provided in Title 3 of Appendix A all international travel will be air, tourist class. However, reimbursement may be made pursuant hereto for an amount of excess baggage for each traveler so as to permit the total amount of such baggage which would have been permitted by first-class air transportation fares.

8. No provision is made herein for reimbursement of insurance premiums.

B. Logistic Support and Costs Reimbursable in Sucres

The Contractor shall be provided with or reimbursed in sucres by the GOE for the following items of local support:

1. Three copies each of all existing aerial photos, photo indexes, and maps of the Guayas River Basin area, some to be furnished in total by GOE prior to July 20th, 1963. In the event that these terms are not met the Contractor cannot be held responsible for fulfilling the terms of Article I-A, sections 1 and 2.

2. Furnished office space for 7 technicians.

3. Use of drafting equipment.

4. Two draftsmen for two months each.

5. Three aerial reconnaissance trips over the area.

6. Transportation within Ecuador including the use of one "jeep", driver, and gasoline, based in Quito for 60 days, and one "jeep", driver, and gasoline, based in Guayaquil for 60 days.

7. Internal commercial air travel Quito-Guayaquil-Quito to a maximum of 16 round trips.

8. Office supplies.

9. Two bilingual secretaries for 60 days.

10. Four counterpart technicians during the stay of the contract technicians in Ecuador.

ARTICLE IV - METHOD OF PAYMENT

A. U.S. Dollars

(1) The GOE will pay the U.S. dollar costs of this contract directly to the Contractor upon submission of the documentation required under Clause 28 of the General Provisions as follows:

The Contractor may bill the GOE either biweekly or monthly and the GOE will reimburse him accordingly for expenses incurred during the previous period.

(2) All payments made by GOE to the Contractor or by the Contractor to his employees under this contract shall be exempted from direct or other taxation and levies which may now or hereafter be imposed by the GOE; if such exemption is not allowed, the amounts of such taxation or levies shall be reimbursed by the GOE. In no event shall such payments or reimbursements be considered as dollar reimbursable costs hereunder.

B. Sucre Costs

These contract costs which are specified as local currency costs in Article III, B, if not furnished in kind by the GOE shall be paid to Contractor in a manner adapted to the local situation and as agreed to by GOE and Contractor. The documentation for such costs shall be on such form and in such manner as GOE shall prescribe.

C. Final Payment

Upon completion of the work and its acceptance by GOE, and upon the furnishing by the Contractor of a release, in such form and such exceptions as may be approved by the Contracting Officer, of all claims against GOE, under or arising out of this contract, accompanied by a satisfactory accounting for all GOE-owned property for which it had custodial responsibility hereunder; GOE or USAID/Ecuador shall pay to the Contractor the unpaid balance of allowable costs and fixed fee (if any) less (i) deductions due under the terms of this contract, and (ii) any sum required to settle any unsettled claim which GOE may have against the Contractor in connection with this contract.

ARTICLE V - SPECIAL AND GENERAL PROVISIONS

The parties hereto agree to be bound by the special provisions set forth herein next below and by all the general provisions set forth in "Appendix A, Cost Provisions." "Appendix B, General Provisions" attached hereto and made a part hereof except as such general provisions are modified herein.

Approval by USAID

Where any action by the Contractor under the contract requires or provides for the consent or approval of GOE, such action shall also require the consent or approval of USAID/Ecuador. Where the contract requires modification by the Contractor to the GOE or any report by the Contractor to GOE, such modification or report shall also be made to USAID/Ecuador.

Approvals to be given by GOE under the contract will be binding on AID only if signed by the Director or Acting Director USAID/Ecuador or by an official of USAID/Ecuador designated in writing by the Director or Acting Director to act in his behalf in respect to the contract or the specific matter involved.

IN WITNESS WHEREOF, the parties hereto have executed this contract on the day and year first hereinabove written which is the date of signing by the last signatory hereto.

For the
REPUBLIC OF ECUADOR

BY: Clemente Yerovi Indaburu (signed)
Contracting Officer

TITLE: President of the National Planning and Economic Coordination Board

DATE: June 28, 1963

For the
PAN AMERICAN UNION OF THE ORGANIZATION OF AMERICAN STATES

BY: Walter J. Sedwitz (signed)
Contracting Officer

TITLE: Acting Assistant Secretary for Economic and Social Affairs
Pan American Union

DATE: June 28, 1963

I, Wm. Sanders (signed) certify that I am the Assistant Secretary General of the Corporation named as Contractor herein; that W. J. Sedwitz, who signed this contract on behalf of the Contractor, was then Acting Assistant Secretary for Economic and Social Affairs of said corporation; that said contract was duly signed for and in behalf of said Corporation by authority of its governing body, and is within the scope of its corporate powers.

IN WITNESS WHEREOF, I have hereunto affixed my hand and seal of said corporation, this seventh day of August 1963.

Wm. Sanders (signed)

Corporate seal

Witness as to signature of Contractor

Suzanne T. Dater (signed)
Administrative Assistant,
Pan American Union

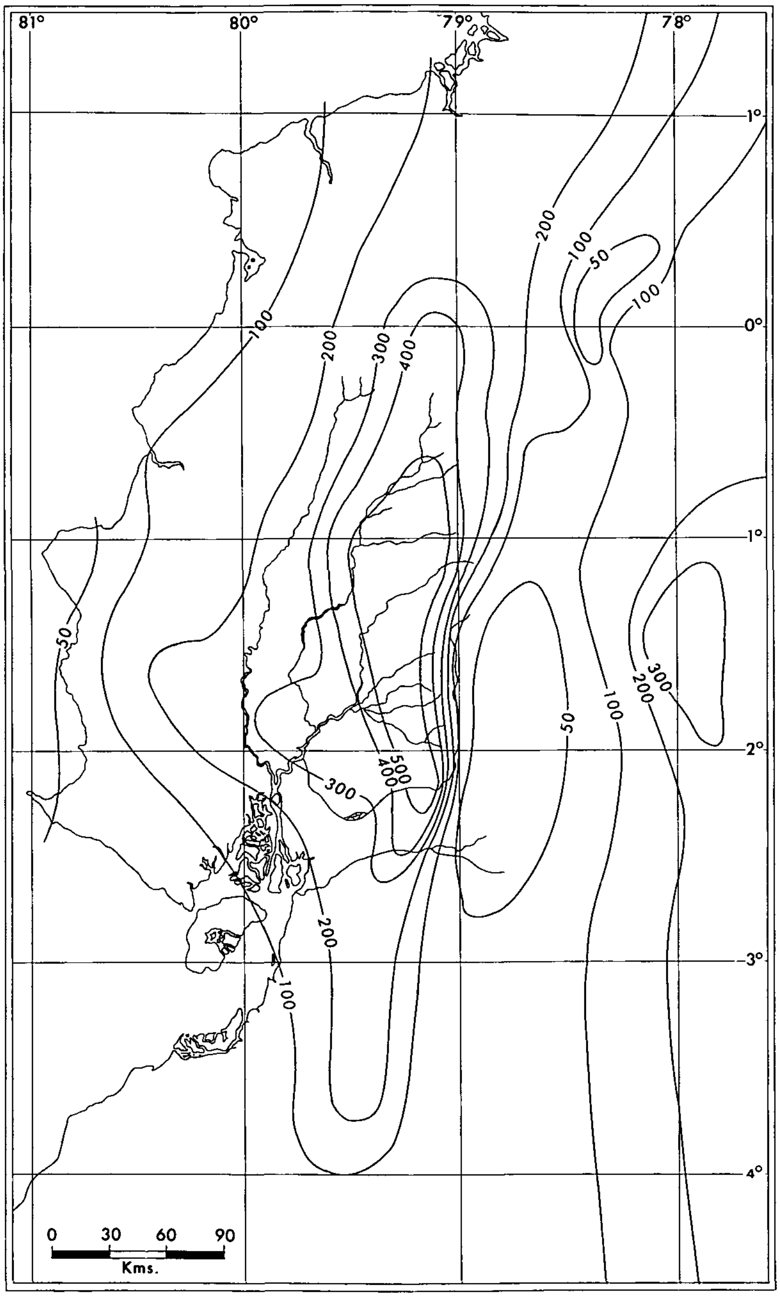
APPENDIX B

Monthly Rainfall Graphs

ENERO
(JANUARY)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



ENERO
(JANUARY)

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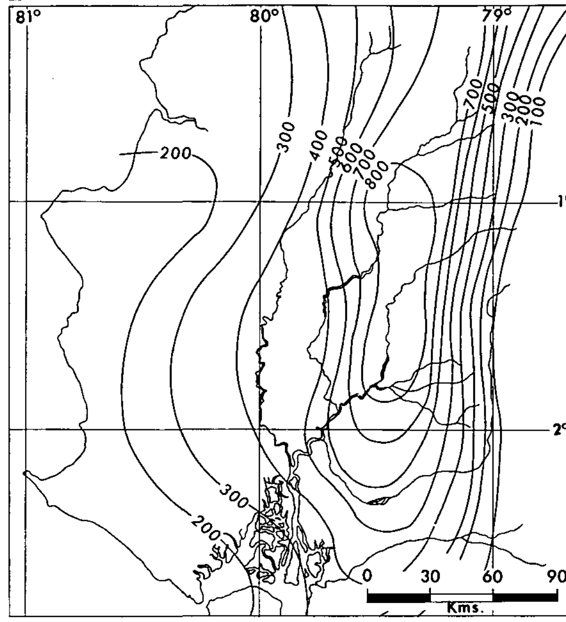
(ABSOLUTE MAXIMUM MONTHLY RAINFALL IN MILLIMETERS)



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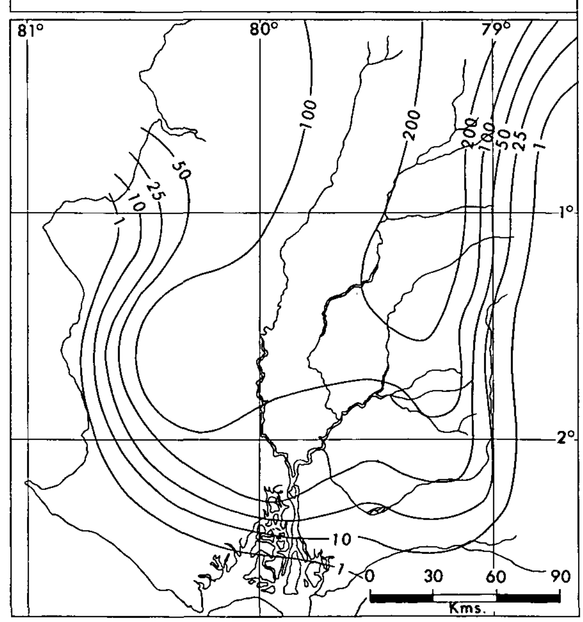

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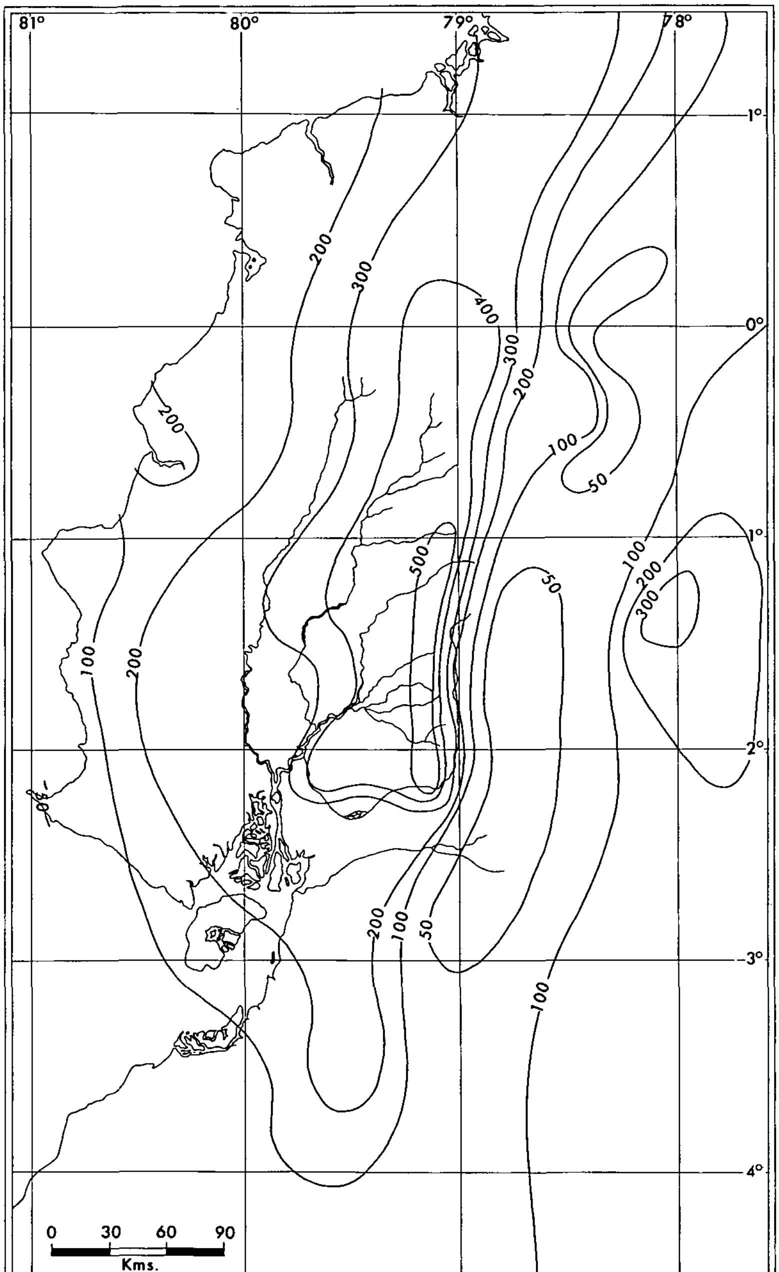
(FEBRUARY)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



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(FEBRUARY)

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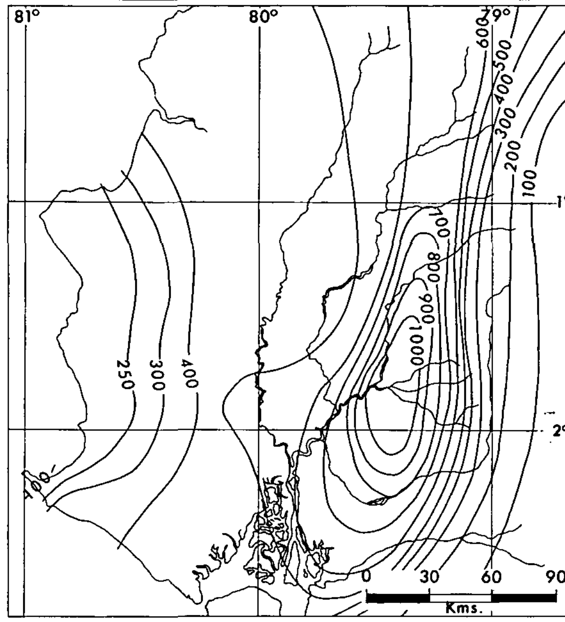

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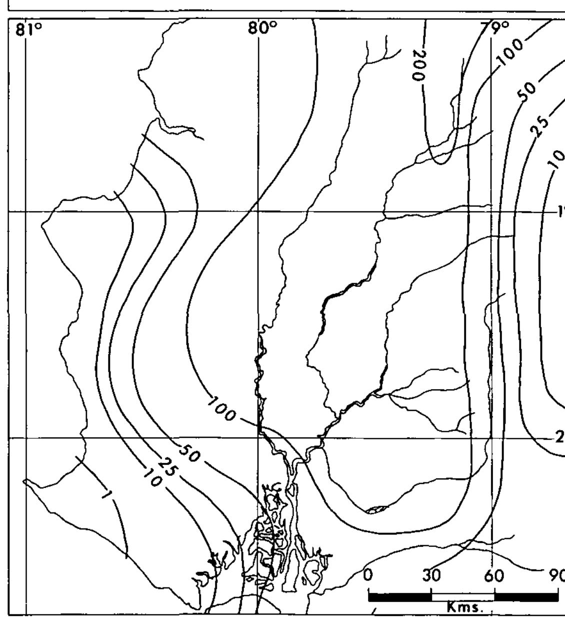

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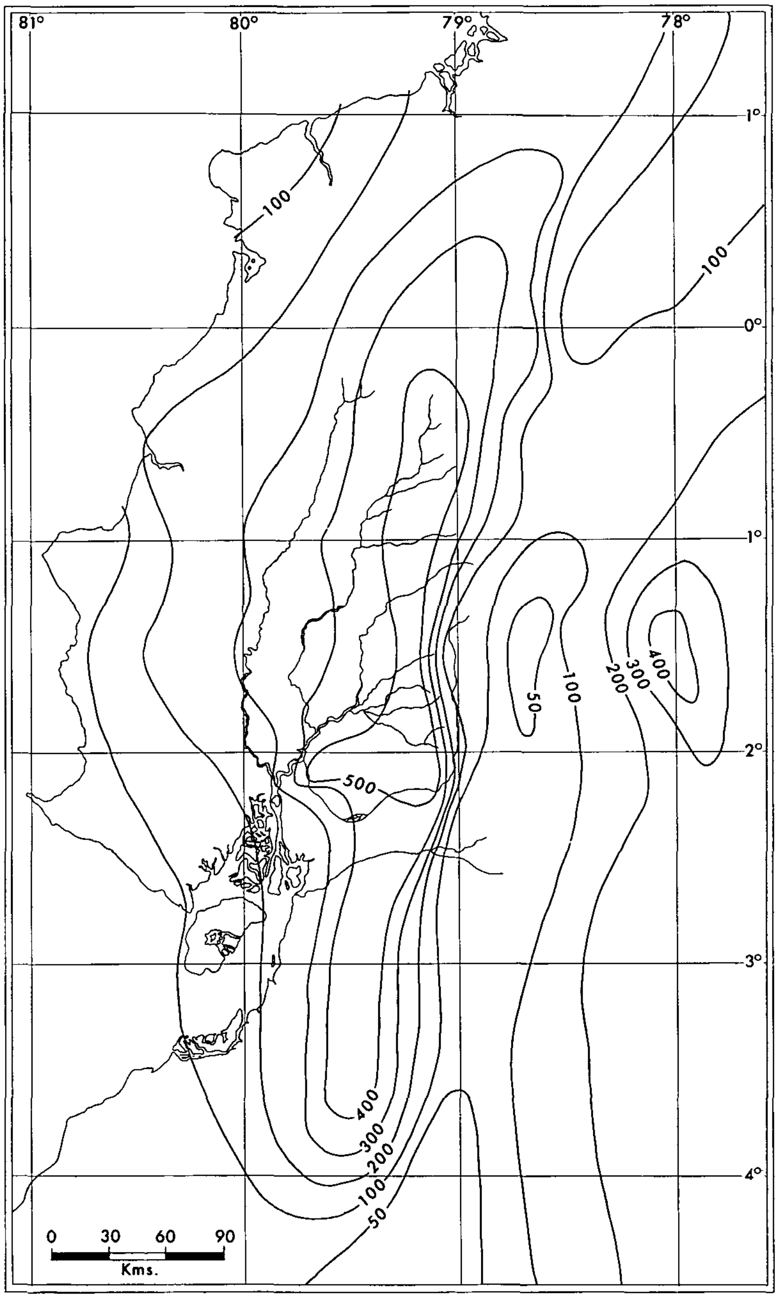
(MARCH)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



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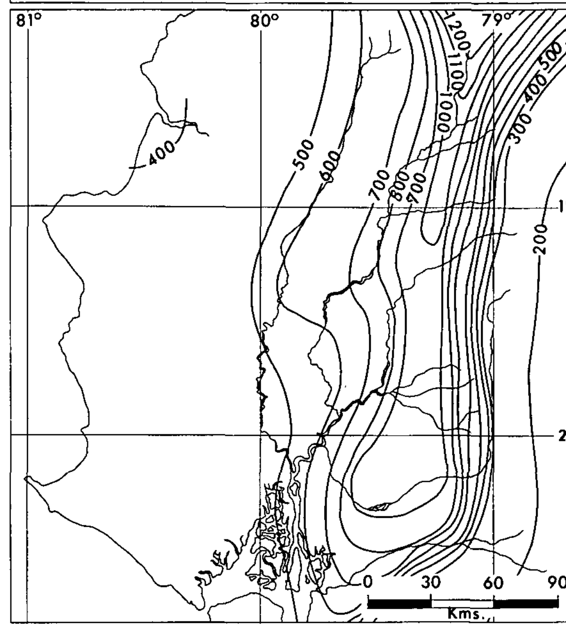

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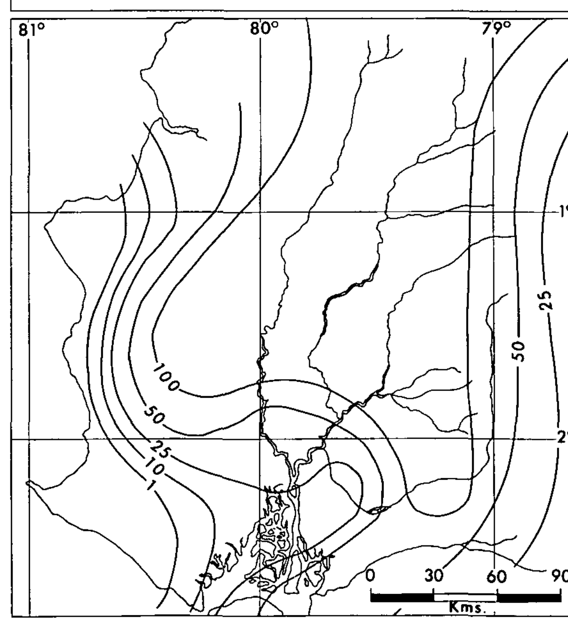

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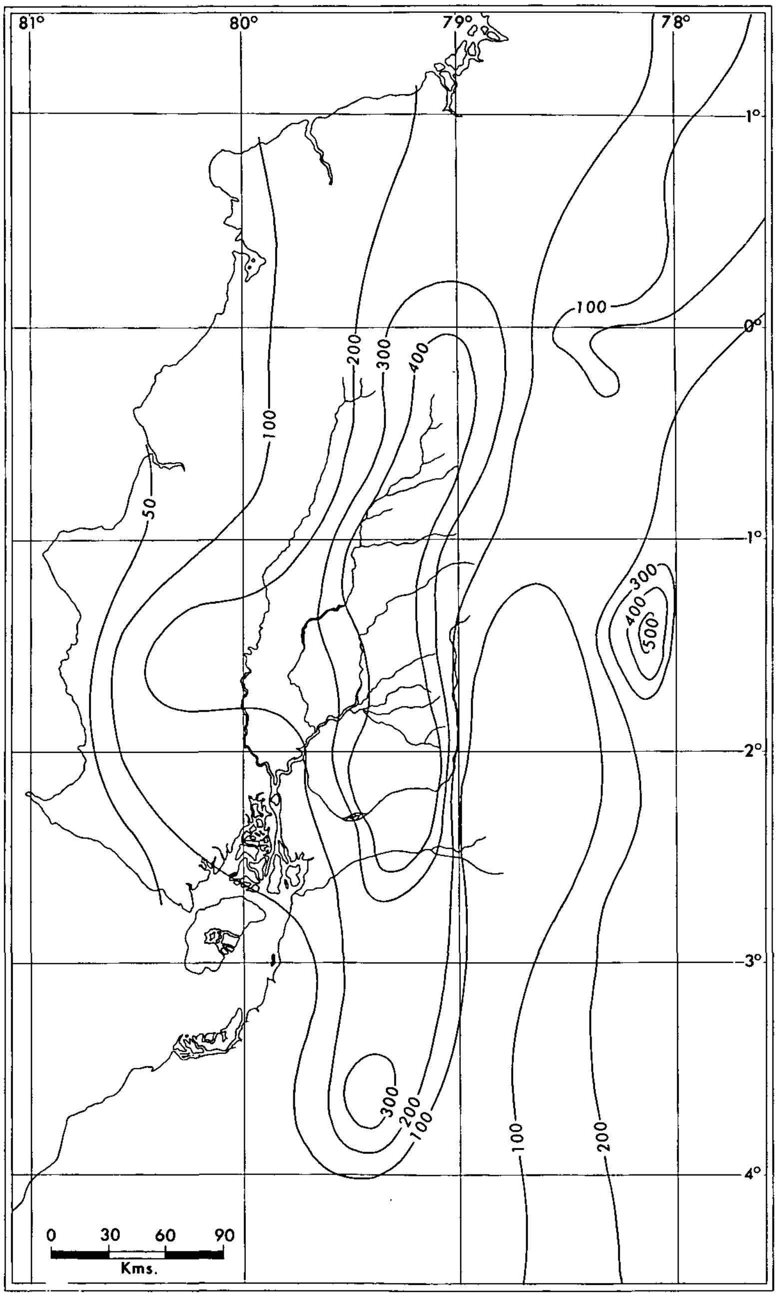

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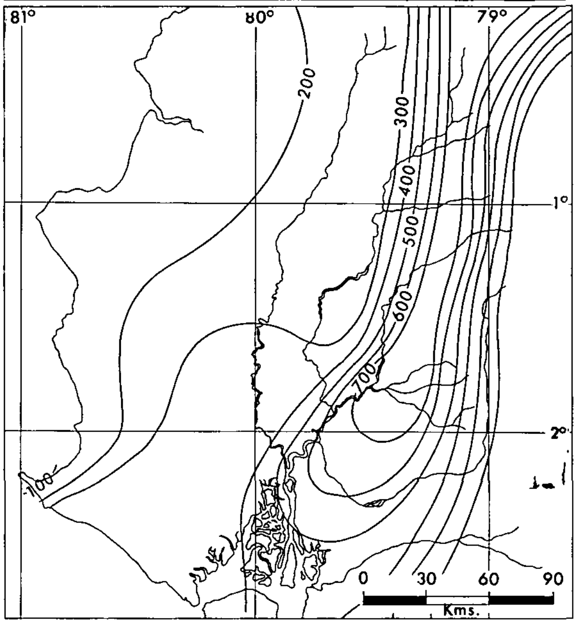

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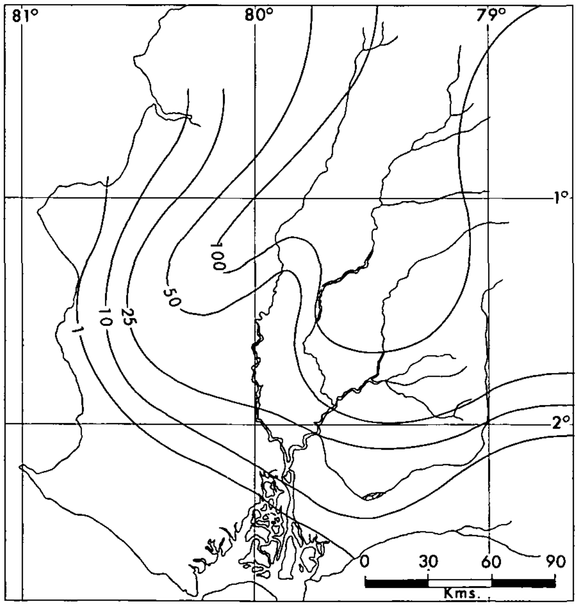

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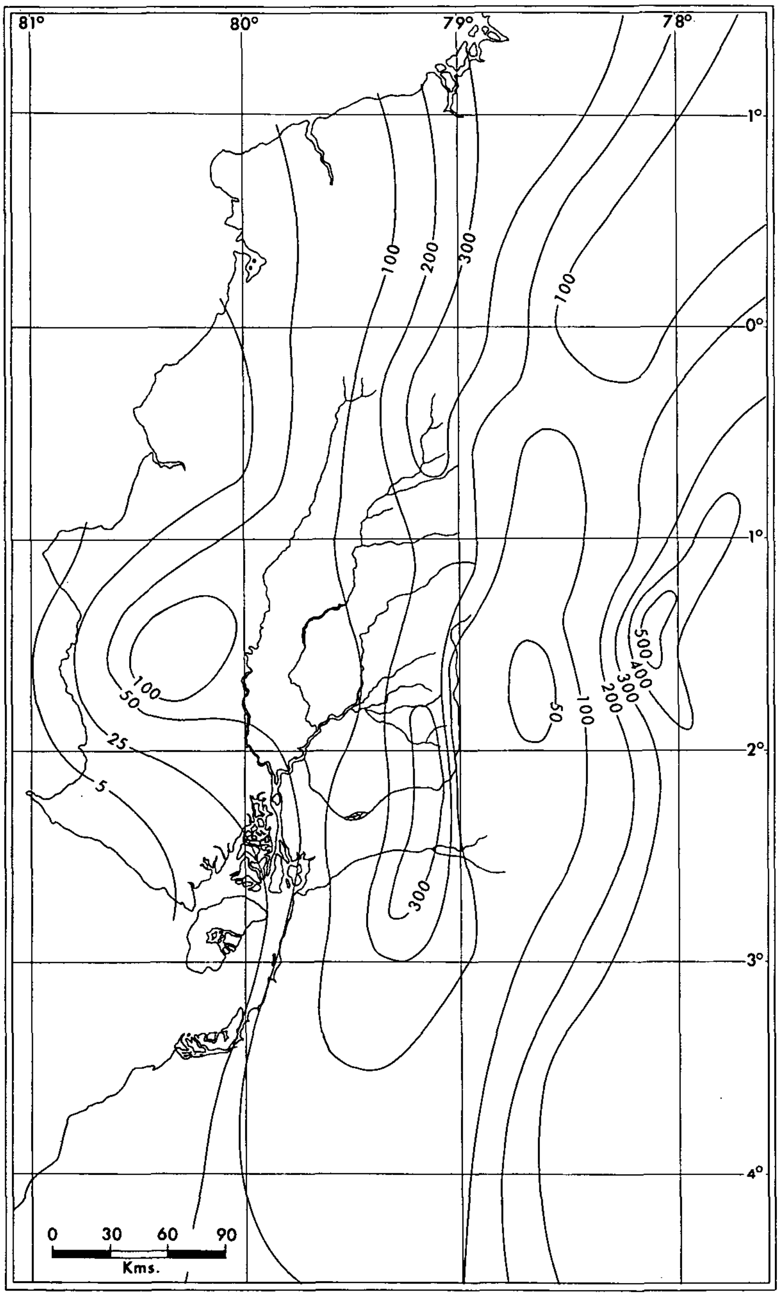

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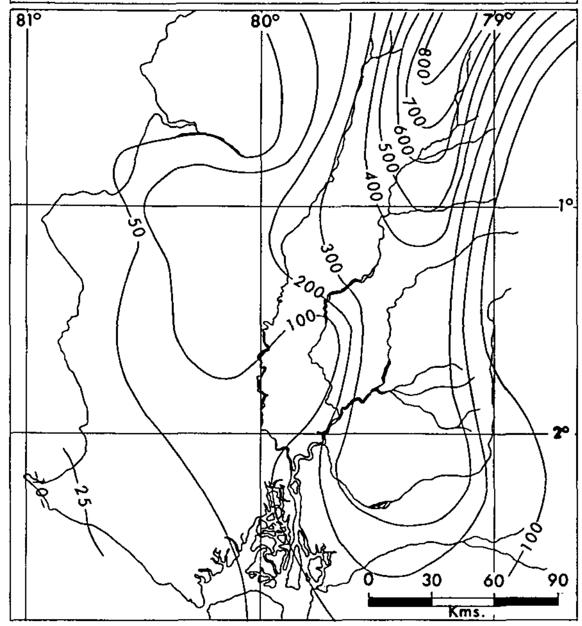

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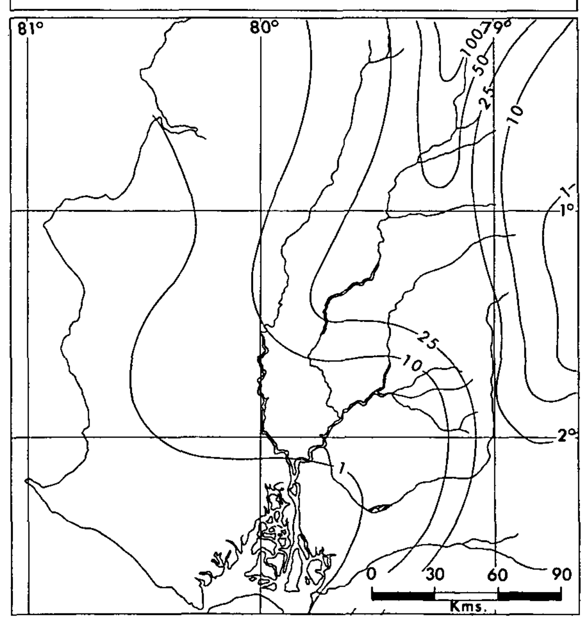

JUNIO
(JUNE)

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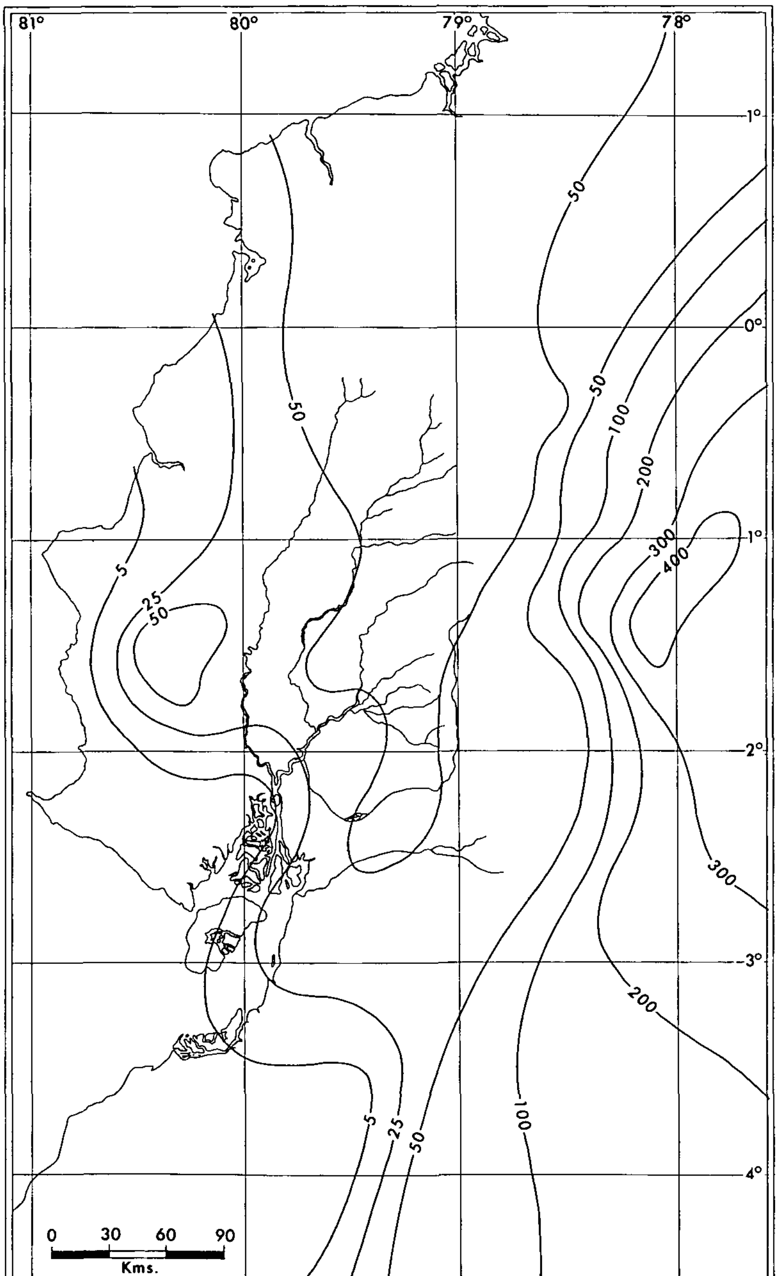
(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



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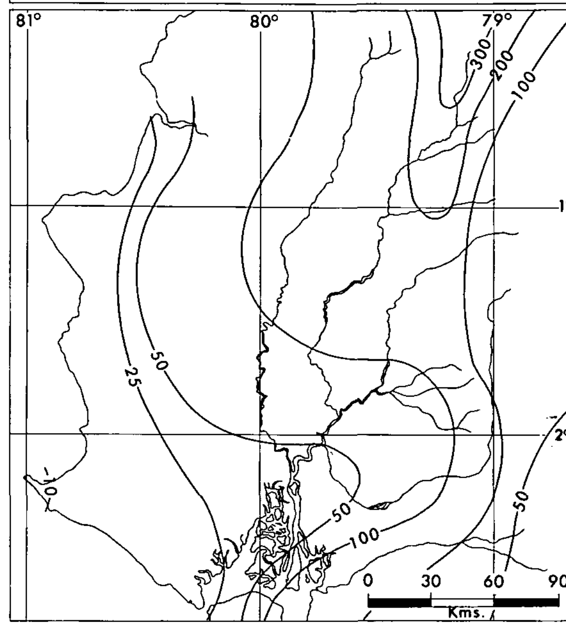

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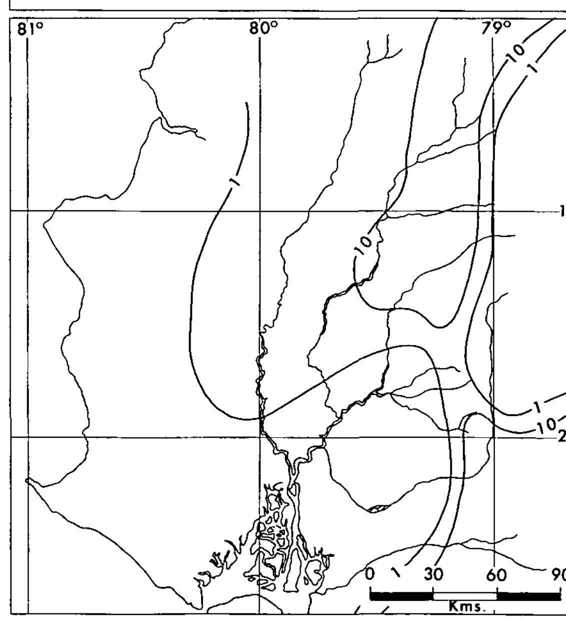

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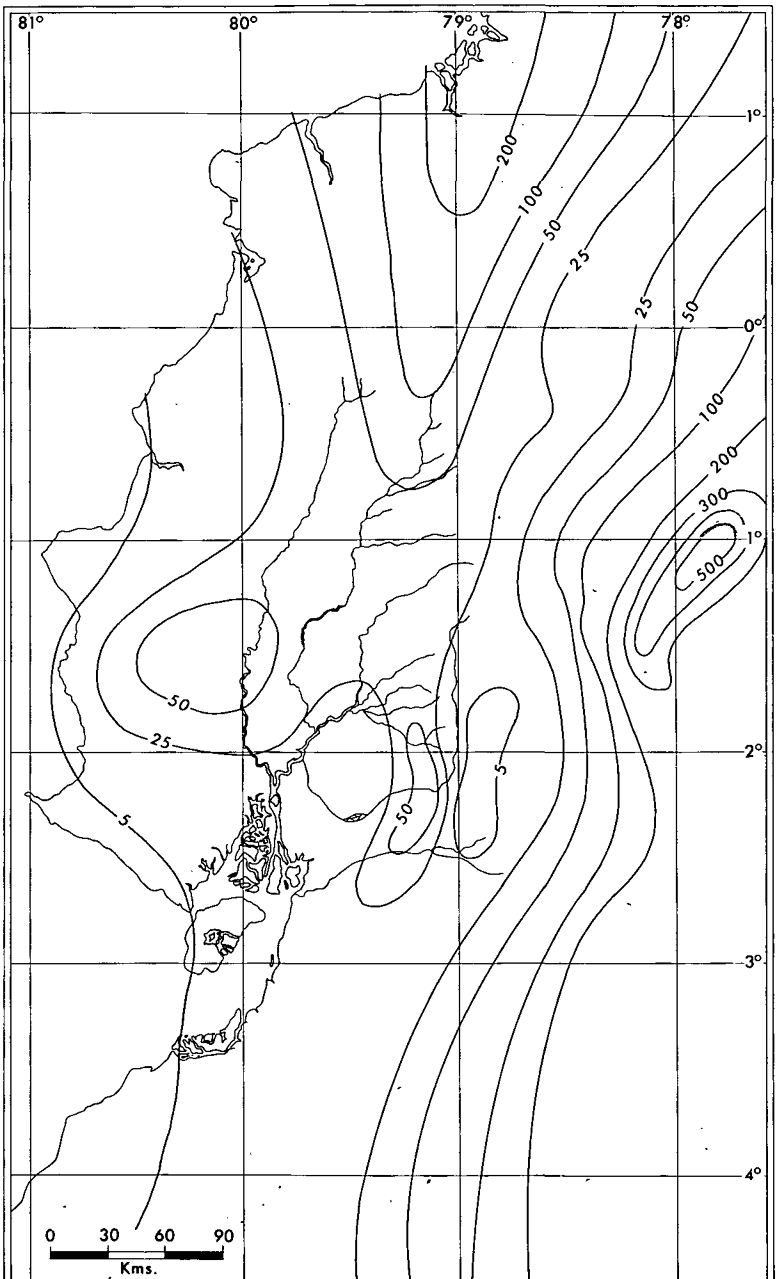

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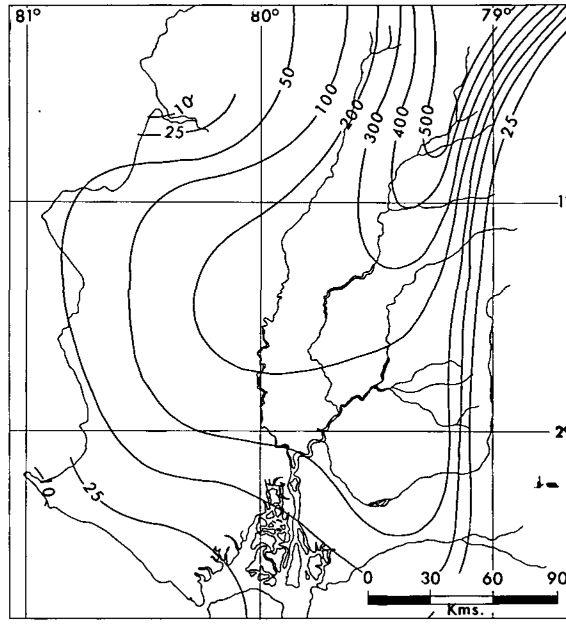

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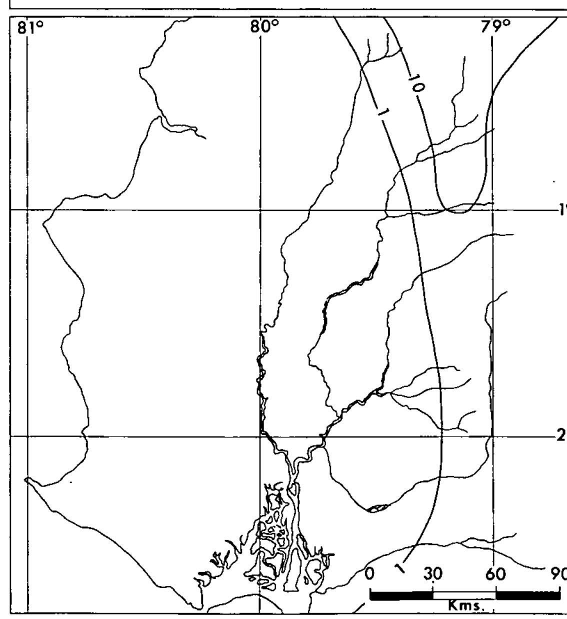
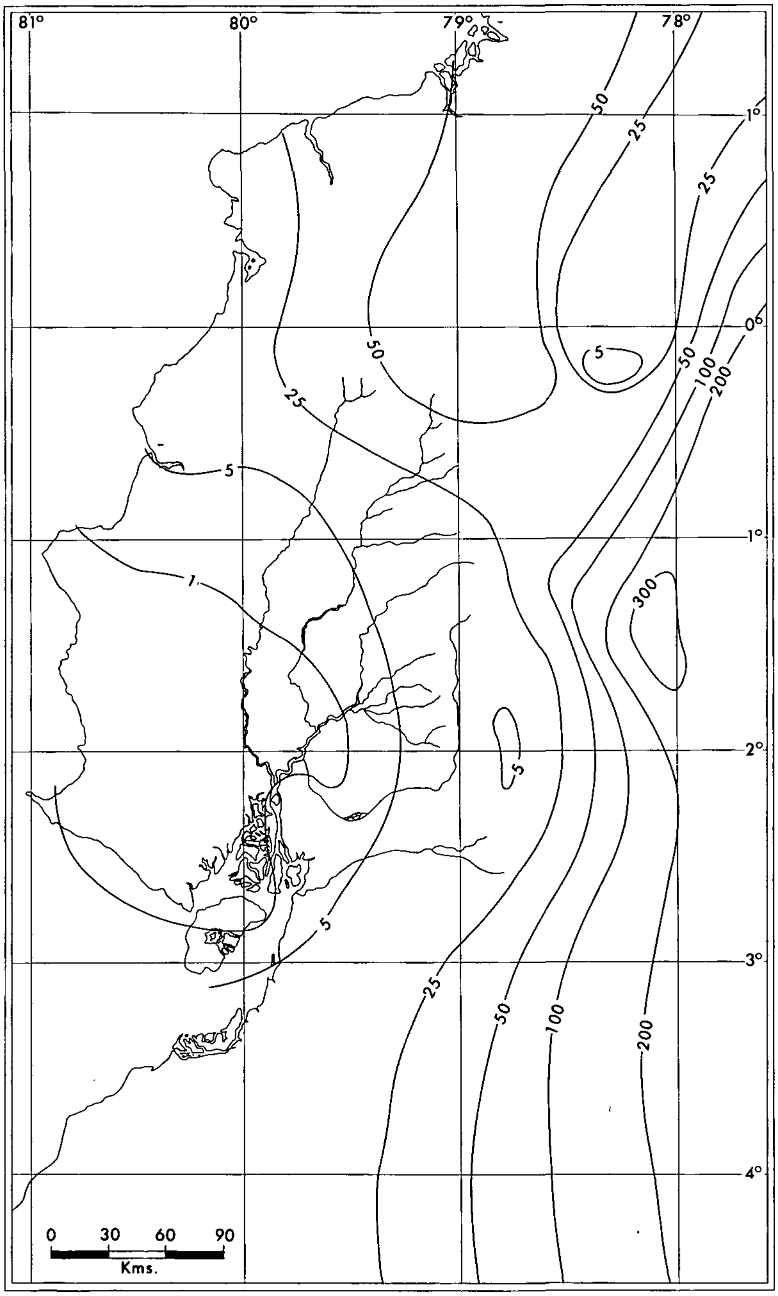


AGOSTO
(AUGUST)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



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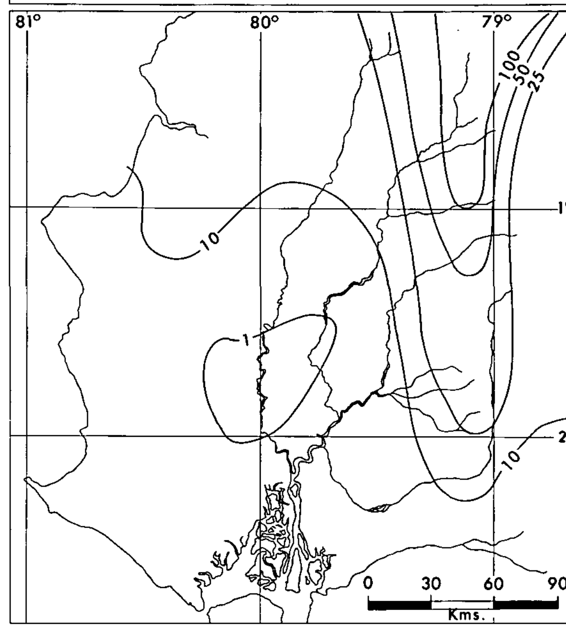

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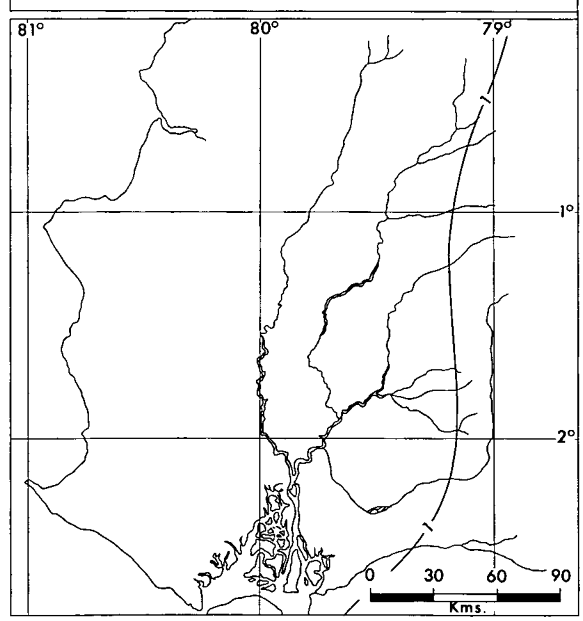

SETIEMBRE
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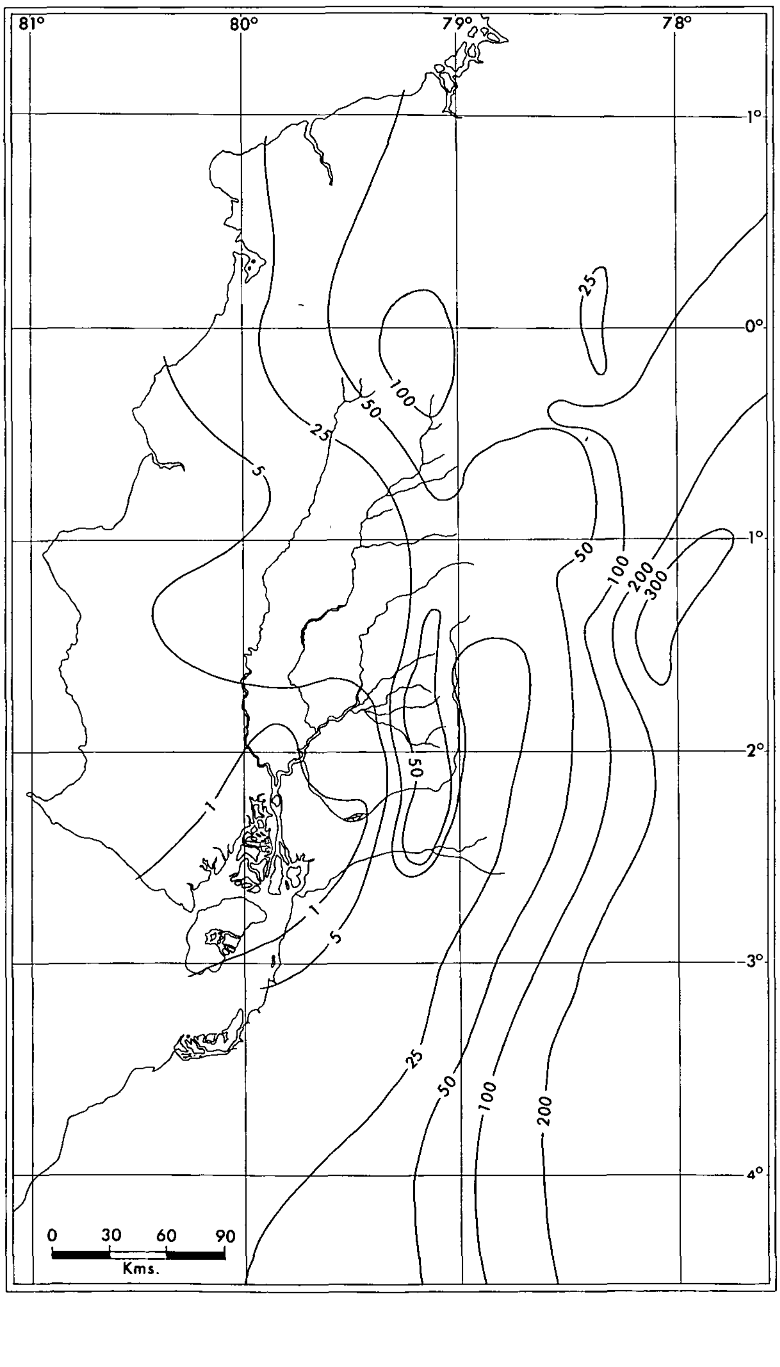
(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



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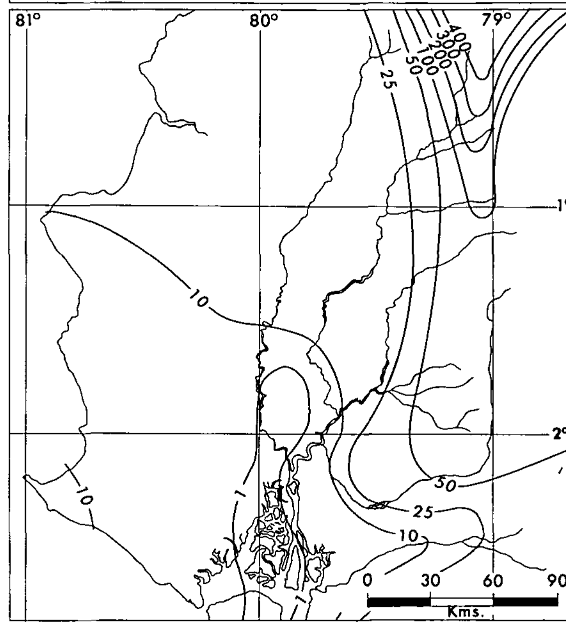

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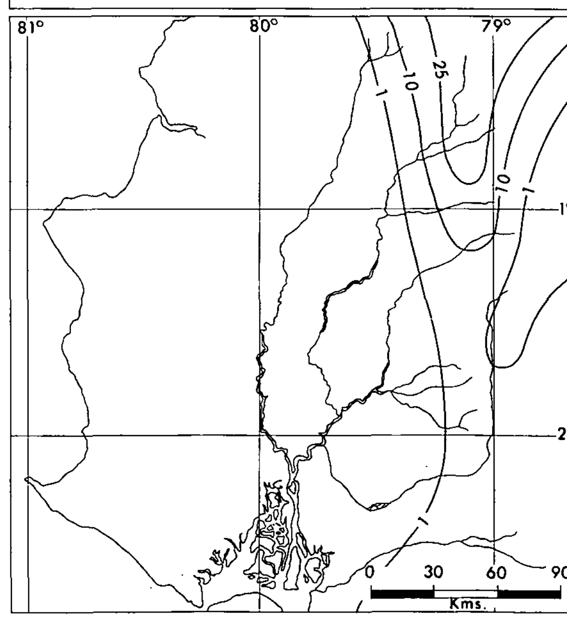
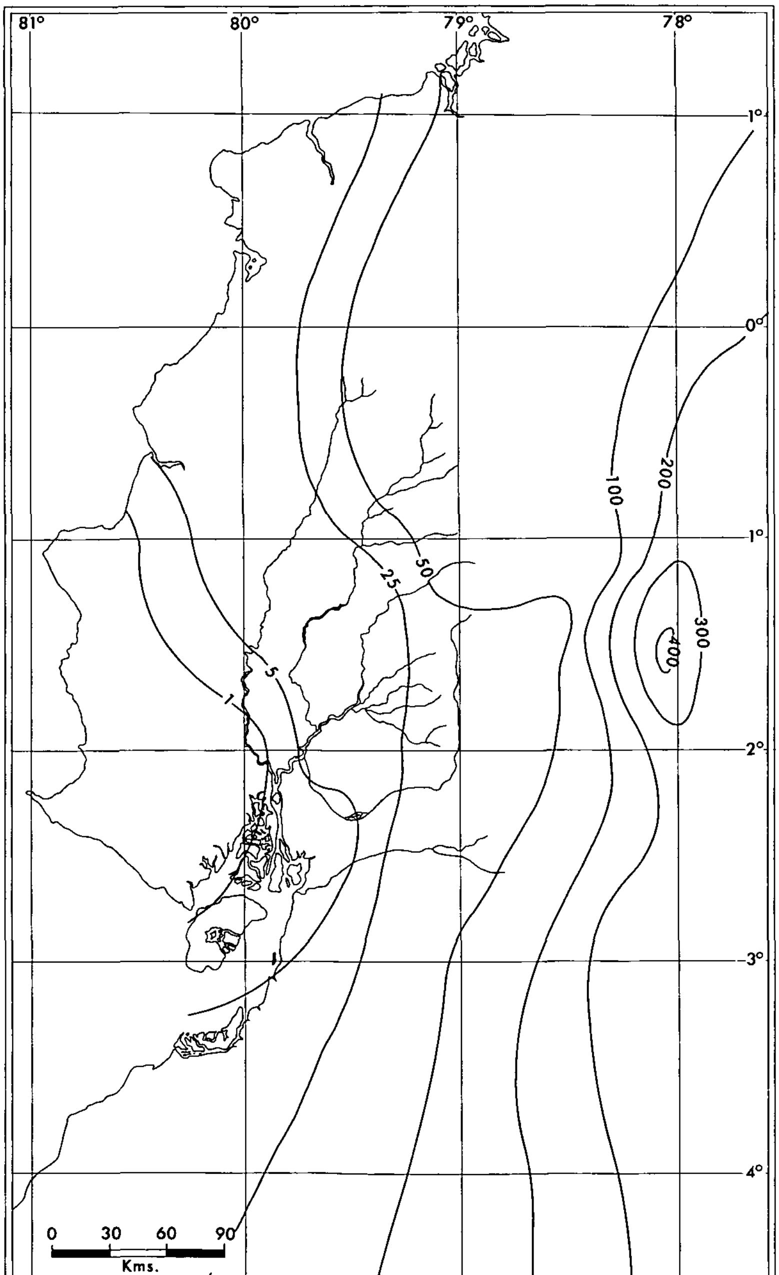
(ABSOLUTE MINIMUM MONTHLY RAINFALL IN MILLIMETERS)



OCTUBRE
(OCTOBER)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



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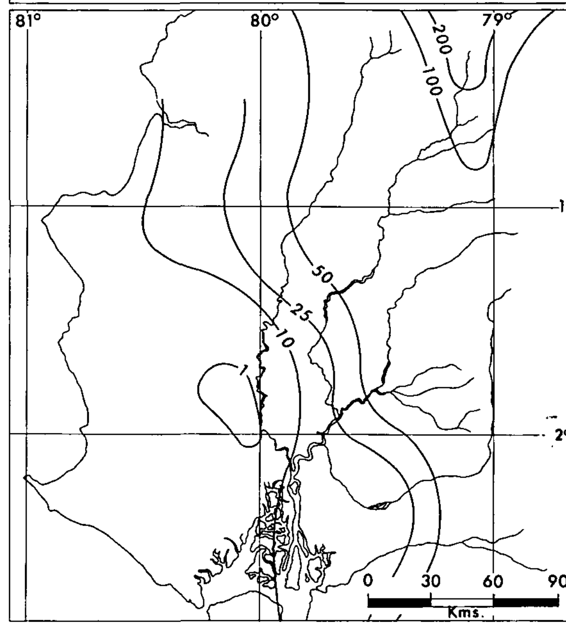
(ABSOLUTE MAXIMUM MONTHLY RAINFALL IN MILLIMETERS)



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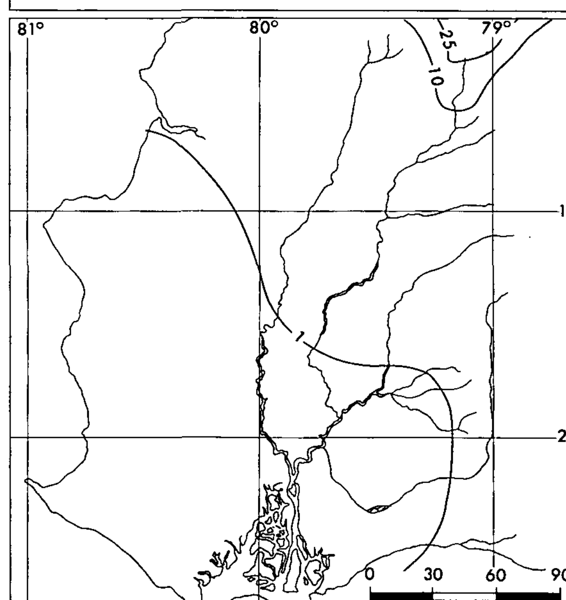

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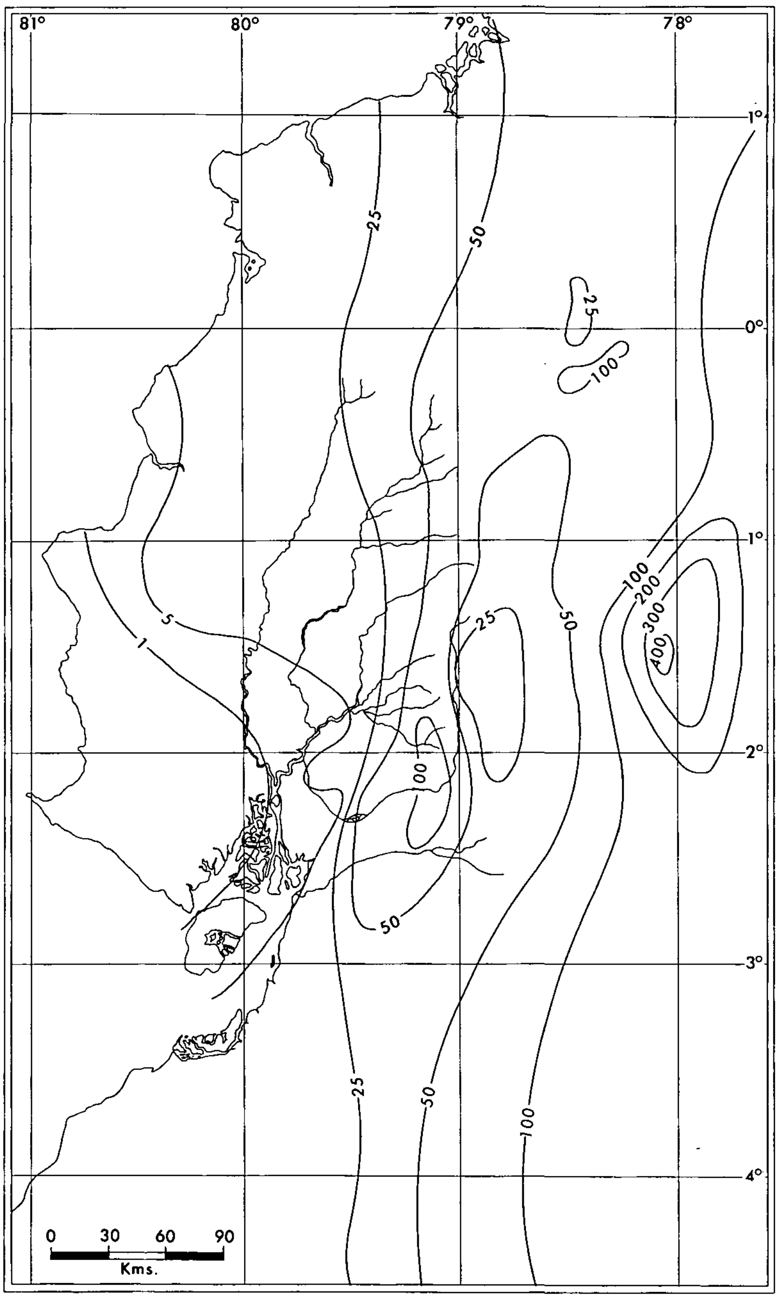
(NOVEMBER)
PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS
(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



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(NOVEMBER)
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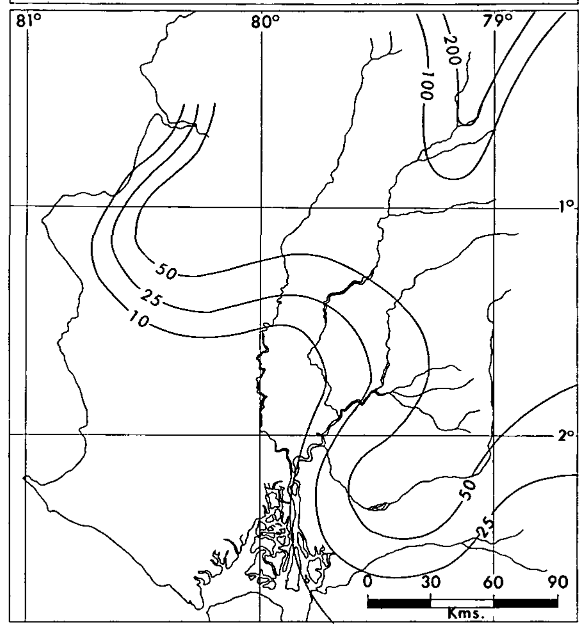

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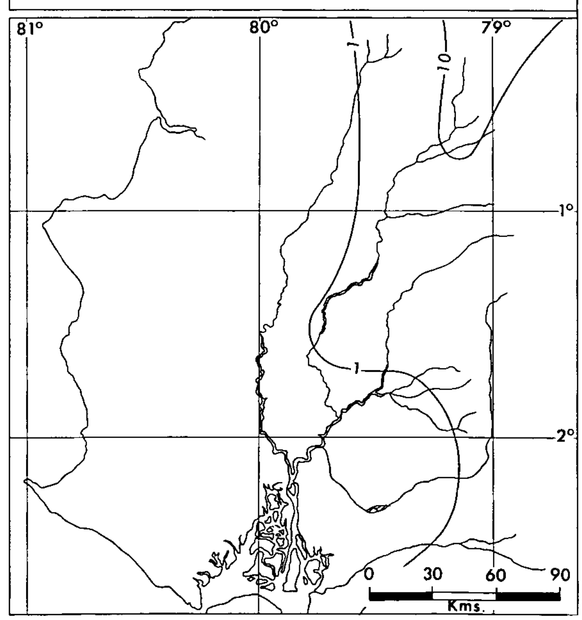
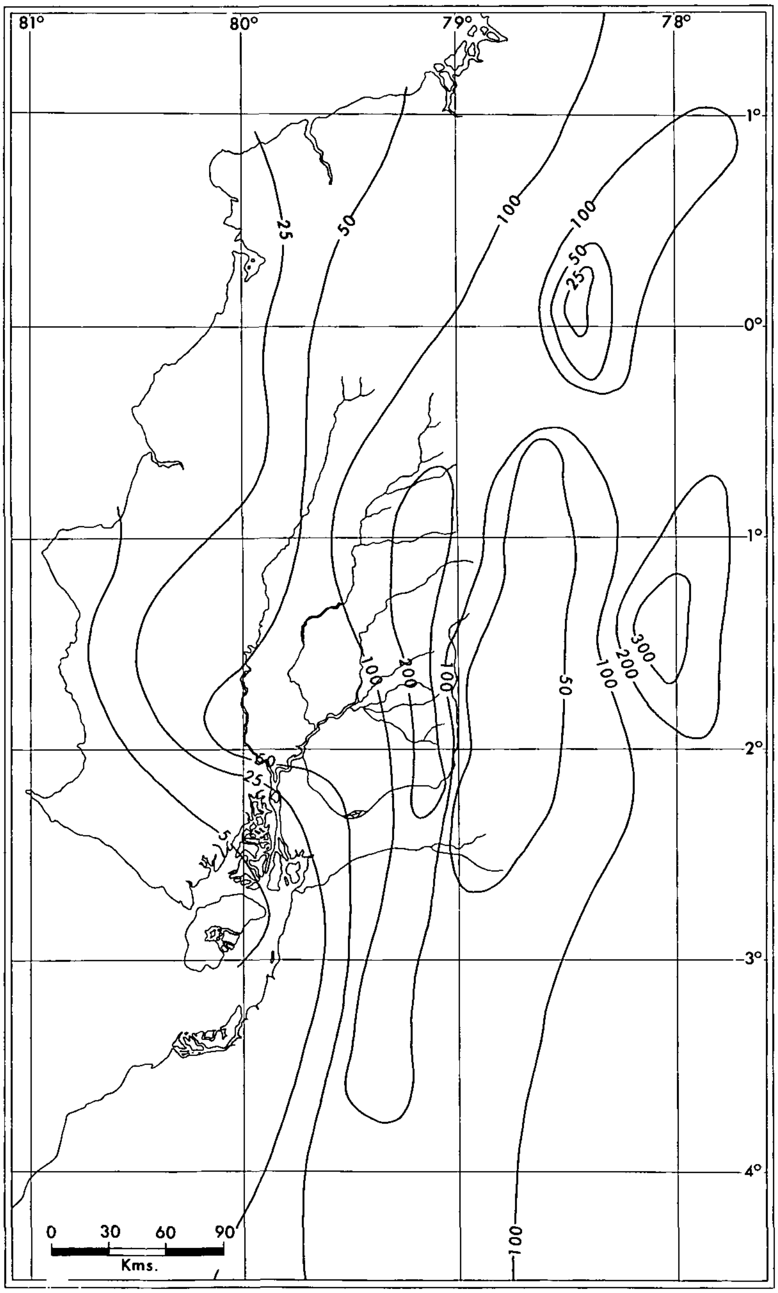


DICIEMBRE
(DECEMBER)

PROMEDIO DE PRECIPITACION MENSUAL EN MILIMETROS

(AVERAGE MONTHLY RAINFALL IN MILLIMETERS)



DICIEMBRE
(DECEMBER)

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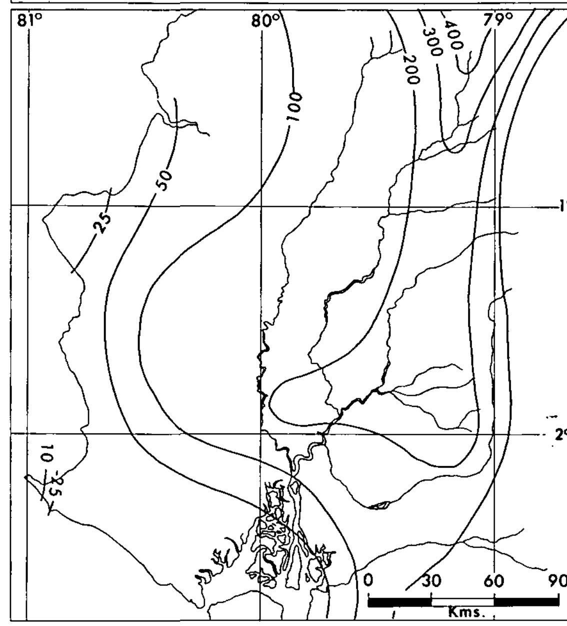
(ABSOLUTE MAXIMUM MONTHLY RAINFALL IN MILLIMETERS)



DICIEMBRE
(DECEMBER)

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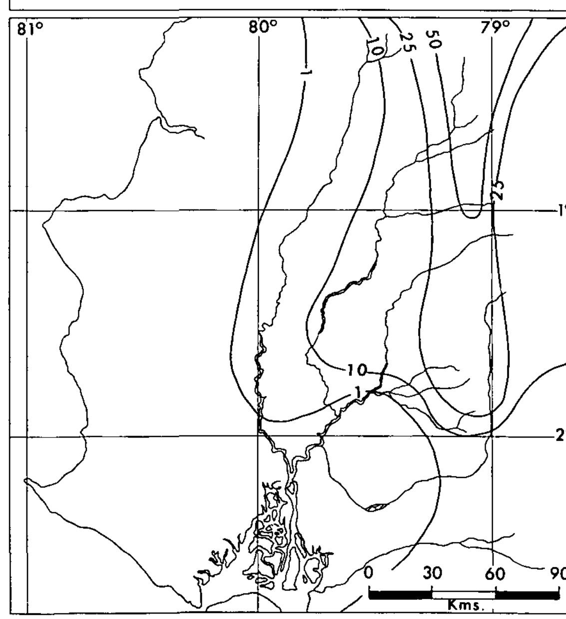
(ABSOLUTE MINIMUM MONTHLY RAINFALL IN MILLIMETERS)



APPENDIX C

Soil Associations– Profile Descriptions

Profile 1

San Miguel Clay

Association	Oro
Province	Manabí
Site	6 km. west of Pichincha on road to Quevedo
Elevation	260 meters above sea level
Slope	60%
Precipitation	1,400 mm. (estimated)
Parent Material	Tertiary sediments
Natural Vegetation	Broadleaf deciduous
Actual Use	Pasture
Drainage	Fair internal, excellent external

Profile

A	0 - 30 cm.	very dark grayish brown (10 YR 3/2 dry) clay, hard and blocky when dry, moderate organic matter pH 6.0 lower boundary indistinct.
B	30 - 60 cm.	reddish brown (5 YR 4/4 dry) clay hard and blocky when dry, few roots, very little organic matter, pH 6.5 lower boundary a transition zone.
C	60 - 250 cm.	red (2.5 YR 4/8 dry) clay with light brownish gray (2.5 Y 6/2 dry) mottles, hard, blocky, no roots, no organic matter, pH 5.7 lower boundary rock.
D	250 cm. plus	light brownish gray (2.5 Y 6/2 dry) rock apparently old sea sediments.

Profile 2

Balzar Clay Loam

Association	Balzar
Province	Guayas
Site	12 km. east of Pichincha on the road to Quevedo
Elevation	240 meters above sea level
Slope	30%
Precipitation	1,200 mm. (estimated)
Parent Material	Volcanic ash over Tertiary sediments
Natural Vegetation	Broadleaf deciduous
Actual Use	Pasture
Drainage	Fair internal, excellent external

Profile

A	0 - 30 cm.	dark grayish brown (10 YR 4/2 dry) clay loam, small blocky, hard when dry, moderate organic matter, pH 5.7 lower boundary indistinct transition zone.
A_b*	30 - 120 cm.	light yellowish brown (10 YR 6/4 dry) clay, blocky, hard when dry, little organic matter, some roots, pH 5.2. This is a buried horizon, lower boundary a transition zone.
B_b*	120 - 200 cm.	yellowish brown (10 YR 5/6 dry) clay with some brown mottles. Hard when dry, blocky, little organic matter, pH 4.9 lower boundary changes to heavily mottled area with lenses of sand, roots, etc.

* A_b and B_b are buried horizons of a previous soil surface.

Profile 3

Ayora Clay

Association	Ayora
Province	Guayas
Site	2 km. west of Pedro Carbo toward Portoviejo
Elevation	60 meters above sea level
Slope	10%
Precipitation	600 mm. (estimated)
Parent Material	Tertiary marine sediments
Natural Vegetation	Upland dry scrub forest
Actual Use	Pasture
Drainage	Fair internal, fair external

Profile

A	0 - 10 cm.	very dark grayish brown (10 YR 5/0 dry) clay, hard columnar, moderate organic matter, pH 5.6 lower boundary a transition zone.
B	10 - 100 cm.	vary pale brown (10 YR 7/4 dry) silt with a few brown mottles, weak columnar structure little organic matter, pH 5.1 lower boundary a transition zone.
C	100 cm. plus	olive yellow (2.5 Y 6/4 dry) silt loam columnar structure with black bands (10 YR 2/1 dry) between structures, no organic matter, pH 5.6

Profile 4

Daule Clay

Association	Daule
Province	Guayas
Site	4 km. south of Palestina on the road to Daule
Elevation	20 meters above sea level
Slope	0%
Precipitation	1,400 mm. (estimated)
Parent Material	Alluvial
Natural Vegetation	Grass
Actual Use	Rice, corn
Drainage	Fair internal, poor external

Profile

1	0 - 20 cm.	gray (7.5 YR 6/0 dry) clay, hard when dry, blocky, moderate organic matter, pH 5.3 lower boundary clear.
2	20 - 200 cm.	dark grayish brown (10 YR 6/1 dry) clay, hard when dry, blocky, little organic matter, some gray mottles, pH 6.1 lower boundary not determined.
3	200 cm. plus	water table.

Profile 5

Vinces Clay

Association	Vinces
Province	Los Ríos
Site	13 km. north of Babahoyo on road to San Juan
Elevation	40 meters above sea level
Slope	0%
Precipitation	1,400 mm. (estimated)
Parent Material	Alluvium
Natural Vegetation	Grass
Actual Use	Pasture
Drainage	Poor internal, poor external floods

Profile

1	0 - 5 cm.	gray (5 Y 6/1 dry) organic matter, little structure, pH 5.4 lower boundary a transition zone.
2	5 - 35 cm.	very pale brown (10 YR 7/4 dry) clay mottled gray (5 Y 6/1 dry) hard, blocky, pH 5.9 lower boundary indefinite.
3	35 cm. plus	light gray (2.5 Y 7/1 dry) clay with brownish yellow (10 YR 6/6 dry) mottles mostly of clay some sand existing as lenses, pH 6.4

Profile 6

Naranjito Fine Sandy Loam

Association	Naranjito
Province	Los Ríos
Site	Pueblo Viejo, 20 km. south of Ventanas on road to Babahoyo
Elevation	45 meters above sea level
Slope	1%
Precipitation	1,600 mm. (estimated)
Parent Material	Alluvium
Natural Vegetation	Broadleaf deciduous
Actual Use	Bananas
Drainage	Excellent internal, excellent external

Profile

1	0 - 20 cm.	light yellowish brown (10 YR 6/4 dry) sandy loam, fine, granular, high in organic matter numerous roots, pH 5.9, lower boundary sharp.
2	20 - 120 cm.	light yellowish brown (10 YR 6/4 dry) silt loam mottled lightly with brown oxides of iron, almost no structure, soft, low bulk density, lower boundary indefinite, pH 6.4
3	120 cm. plus	silty clay mottled gray, small, blocky structure (not sampled)

Profile 7

Maná Fine Sandy Loam

Association	Maná
Province	Cotopaxi
Site	8 km. east of La Maná on Quevedo - Latacunga road
Elevation	770 meters above sea level
Slope	30%
Precipitation	3,000 mm. (estimated)
Parent Material	Volcanic ash
Natural Vegetation	Evergreen broadleaf forest
Actual Use	Sugar cane
Drainage	Excellent internal, excellent external

Profile

1	0 - 10 cm.	brown (10 YR 4/3 dry) fine sandy loam, small subangular blocks, high in organic matter, pH 5.7 lower boundary a transition zone.
2	10 - 70 cm.	olive (5 Y 5/4 dry) fine sandy loam, almost no structure, moderate organic matter, pH 6.0 lower boundary clear wavy.
3	70 - 120 cm.	light gray (2.5 Y 7/2 dry) sand with lenses of yellowish red (5 YR 5/6 dry) sand, little structure, little organic matter, pH 6.0 lower boundary abrupt.
4	120 cm. plus	dark yellowish brown (10 YR 4/4 dry) loam, small subangular blocks, pH 6.1

Profile 8

Chimbo Loam

Association	Chimbo
Province	Bolívar
Site	San Miguel de Chimbo
Elevation	2,390 meters above sea level
Slope	30%
Precipitation	1,000 mm. (estimated)
Parent Material	Volcanic ash
Natural Vegetation	High mountain forest
Actual Use	Eucalyptus grove
Drainage	Excellent internal, excellent external

Profile

1	0 - 40 cm.	yellowish brown (10 YR 5/4 dry) loam fine, blocky, high in organic matter, pH 6.0 lower boundary wavy.
2	40 cm. plus	brown (10 YR 5/3 dry) clay, hard, blocky, moderate organic matter, pH 6.0

Profile 9

Pichilingue Loam

Association	Pichilingue
Province	Los Ríos
Site	Pichilingue Experiment Station 200 yards west of shops
Elevation	80 meters above sea level
Slope	3%
Precipitation	2,500 mm. (estimated)
Parent Material	Volcanic ash
Natural Vegetation	Broadleaf deciduous
Actual Use	Cacao
Drainage	Excellent internal, excellent external

Profile

1	0 - 30 cm.	very dark grayish brown (10 YR 3/3 dry) loam, small blocky with some small (3 mm. diameter) iron concretions, moderate organic matter, pH 6.2 lower boundary indistinct.
2	30 - 90 cm.	yellowish brown (10 YR 5/4 dry) clay loam, small blocky, moderate organic matter, pH 6.5 sharp lower boundary.
3	90 cm. plus	yellowish brown (10 YR 5/8 dry) clay with black (10 YR 2/1 dry) mottles. The mottles increase in size with depth, blocky, sticky when wet, low organic matter, pH 6.0

APPENDIX D

Supporting Cost Schedules

Schedule 1:	Summary of Quantities of Inventory Type Studies Estimated for Each Program Area
Schedule 2:	Estimate of Professional Personnel Requirements
Schedule 3:	Estimate Non-Professional Personnel, Survey Crew and Vehicle Requirements
Schedule 4:	Subcontracts
Schedule 5:	Travel, Per Diem and Allowances
Schedule 6:	Vehicle Costs
Schedule 7:	Equipment Other Than Vehicles
Schedule 8:	Other Direct Costs

Schedule 1

SUMMARY OF QUANTITIES OF INVENTORY TYPE STUDIES ESTIMATED FOR EACH PROGRAM AREA

Activity[a/]	Prog. Area I Component a	Prog. Area I Component b	Prog. Area II Component abc	Prog. Area III Component a	Prog. Area IV Component abc	Prog. Area V Component a	Prog. Area VI (Basin-wide Studies)	Total Quantities
Land Use Mapping (Km^2)	260	3,120	2,610	10,780	2,590			19,360 Km^2
Recon. Soils & Land Cap. Map. (Km^2)		3,120	2,610	10,780	2,590			19,100 Km^2
Semi-detailed Soils & Land Cap. Map. (Km^2)		1,350	1,350					2,700 Km^2
Detailed Soils & Land Cap. Map. (Km^2)	260							260 Km^2
Pre-exploitation Forest Inventory (Km^2)			1,070					1,070 Km^2
Exploratory Forest Inventory (Km^2)						2,420		2,420 Km^2
Sustained Yield Forest Inventory (Km^2)						1,200		1,200 Km^2
Property Mapping (parcels)		9,000[b/]	4,000					13,000 Parcels
Subcontract Mosaics (Km^2)	260	3,120	2,610	10,780	2,590	2,420		21,780 Km^2
Subcontract Topograhic Mapping (Km^2)	105							105 Km^2
Subcontract Drilling (meters)		610		610				1,220 m.
Aerial Photos from Gov't. Ecuador								
1:60,000 - 2 sets contact prints								21,780 Km^2
1:20,000 - 3 sets contact prints								21,780 Km^2

a. See general specifications for more detailed information on each activity.

b. This figure includes properties to be mapped in Program Area I, Component a, as well as Component b.

Schedule 2

ESTIMATE OF PROFESSIONAL PERSONNEL REQUIREMENTS

	Engineering Studies (Man-Months)								Inventory Studies (Man-Months)								Totals				
	Prog. Area I Comp. a	Prog. Area I Comp. b	Prog. Area II Comp. abc	Prog. Area III Comp. a	Prog. Area IV Comp. abc	Prog. Area V Comp. a	Prog. Area VI (Basin-wide)	Sub-Total (Man-Month)	Land Use	Recon. Soils & L.C.	Semi Det. Soils & L.C.	Det. Soils & L.C.	Pre-Explt. For. Invt.	Expl. & Sust. Yield Invt.	Property Mapping	Sub-Total (Man-Month)	Number of Personnel	Mobilization (Man-Month)	Total (Man-Months)	Rate (Average for all professionals)	TOTAL DOLLARS
Foreign Professionals																					
Agronomist	5	6	5.5	10	6		7	39.5									2	1	40.5	$1,000	$40,500
Irrigation & Drainage Engineer	5	10		12				27									2	1	28	1,000	28,000
Agricultural Engineer			10					10									1	.5	10.5	1,000	10,500
Colonization Specialist			10					10									1	.5	10.5	1,000	10,500
Hydrologist		5		5			5	15									1	.5	15.5	1,000	15,500
Forestry Specialist				3.5	2	6	4.5	16	5				6	16		27	3	1.5	44.5	1,000	44,500
Soil chem. & Fertility Specialist							18	18									1	.5	18.5	1,000	18,500
Land Use Specialist									14							14	1	.5	14.5	1,000	14,500
Soils & Land Capability Specialist										24	24.5	8				56.5	3	1.5	58	1,000	58,000
Hydro Power Engineer					4			4									1	.5	4.5	1,000	4,500
Property Mapping Specialist															10	10	1	.5	10.5	1,000	10,500
Land Tenure Specialist							6	6									1	.5	6.5	1,000	6,500
Social Anthropologist							6	6									1	.5	6.5	1,000	6,500
Agricultural Economist							6	6									1	.5	6.5	1,000	6,500
Civil Engineer							6	6									1	.5	6.5	1,000	6,500
Regional Planner							12	12									1	.5	12.5	1,000	12,500
Sub-total Foreign Professionals	10	21	25.5	30.5	12	6	70.5	175.5	19	24	24.5	8	6	16	10	107.5	22	11	294	$1,000	$294,000
Ecuadorian Counterpart Professionals	10	21	25.5	30.5	12	6	70.5	175.5	19	24	24.5	8	6	16	10	107.5	22		283	330	93,390*
TOTAL PROFESSIONALS	20	42	51	61	24	12	141	351	38	48	49	16	12	32	20	215	44		577		$387,390

*Can be paid in Ecuadorian Currency.

Schedule 3

ESTIMATED NON-PROFESSIONAL PERSONNEL, SURVEY CREW AND VEHICLE REQUIREMENTS

	Engineering Studies (Man-Months)								Inventory Studies (Man-Months)								Totals		
	Prog. Area I Comp. a	Prog. Area I Comp. b	Prog. Area II Comp. abc	Prog. Area III Comp. a	Prog. Area IV Comp. abc	Prog. Area V Comp. a	Prog. Area VI (Basin-wide)	Sub-Totals Man Months	Land Use Map.	Recon. Soils & Land Cap. Map.	Semi-Det. Soils & Land Cap.	Det. Soils & Land Cap. Map.	Pre-Explt. Forest Invt.	Expl. & Sust. Yield Invt.	Property Map.	Sub-Total Man Months	Total Man or Vehicle Months	Rate $ Per Month	Total $
Draftsmen	8	16	16	12	5	5	16	78	14	14	6	2	2	4	38	80	158	130	20,540*
Property Mapping Supervisors															27	27	27	150	4,050*
Property Mappers															149	149	149	130	19,370*
Surveyors (3 man crew)	9	18	18					45									45	100	4,500*
Drivers	9	12	13	16	13	6	43	108	9	17	16	4	4	12		62	170	55	9,350*
Laborers	5	16	14	16	9	15	20	99		34	48	8	12	48		150	249	35	8,715*
Secretary Pool (for all activities)							95	95									95	85	8,075*
Totals	31	62	61	44	27	26	174	425	23	65	70	14	18	64	214	468	893	83.60	74,600*
Vehicle months	9	12	13	16	13	6	43	108	9	17	16	4	4	12	112	174	282	260	73,320**

*Can be paid in Eduadorian currency.

**Can be paid in part in Ecuadorian currency.

SUBCONTRACTS

Schedule 4

1) Test drilling for groundwater studies is needed in Program Areas I and II. A requirement of 1,220 meters of drilling is estimated at a cost of $15.00 per foot.	$ 60,000
2) Topographic mapping is required in Program Area I, Component a. This mapping should be done photogrammetrically to standard specifications from the 1:20,000 photos (6" f/1). Map scale should be 1:2,000 to 1:5,000 depending on the engineers requirement with a two meter contour interval with one meter intermediate contours. 105 Km^2 are to be mapped at an estimated cost of $175.00 per Km^2.	$ 18,375
3) Mosaic compilation of the entire Basin area from 1:60,000 scale photographs using existing control. Delivery items are 75 sheets 114 cm. x 102 cm. covering 21,780 Km^2 at a scale of 1:20,000 screened on cronaflex. Conventional data such as latitude and longitude, title information scale, etc., should appear in the margin and in the mosaic major rivers, towns, roads and other landmark features should be labeled. Cost of mosaic compilation is estimated at $0.37 per Km^2 for the 21,780 Km^2.	$ 8,058
Total of Subcontracts' Costs	$ 86,433

TRAVEL, PER DIEM AND ALLOWANCES

Schedule 5

International travel	$ 25,893**
International travel per diem	5,040
Domestic travel and per diem	6,000
Per diem in Ecuador for U.S. and Ecuadorian field staff	61,970*
Household goods shipment	4,250
Housing allowances	34,615
Total	$137,762***

* Can be paid in Ecuadorian currency.
** Can be paid 50 percent in Ecuadorian currency.
*** Can be paid $28,237 (U.S.) and $109,531 Ecuadorian currency.

VEHICLE COSTS

Schedule 6

Total of 282 vehicle months required derived from schedule of non-professional personnel and vehicle requirements (see Schedule 3).

Per month rate derived as follows:

$5,000 vehicle depreciated over 24 months is per month	$207,00
Maintenance per month	20,00*
Operating costs 825 miles per month at $0.04	33,00*
Total per month costs	$260,00

282 vehicle months at $260.00/month = $73,320 total vehicle costs.**

* Can be paid in Ecuadorian currency

** Can be paid $14,946 in Ecuadorian currency and $58,374 in U.S. Currency.

EQUIPMENT OTHER THAN VEHICLES

Schedule 7

Soils laboratory and field equipment	$ 4,000
Drafting equipment and furniture for 15 draftsmen at $300	4,500
Ozalid machine 42"	2,000
Furniture other than drafting 20 desk and chair units at $200; 20 desk and chair units at $150; other furniture $3,000	10,000*
Other equipment, stereoscopes, measuring devices for photo interpretation, foresters equipment, etc.	10,000
Total	$ 30,500**

* Can be paid in Ecuadorian currency.

** Can be paid $20,500 in U.S. and $10,000 Ecuadorian currency.

OTHER DIRECT COSTS

Schedule 8

Telephone, telegraph, cable, postage, 22 months at $400/month		$ 8,800**
Processing U.S. professionals passports, health examinations, etc., 22 at $100		2,200
Supplies office - 22 months at $150/month		3,300*
Supplies drafting		4,100*
Printing services		3,000*
Office space		27,000*
	Total	$ 48,400***

* Can be paid in Ecuadorian currency.
** Can be paid 50 percent in Ecuadorian currency.
*** Can be paid $6,600 in U.S. and $41,800 in Ecuadorian currency.

APPENDIX E

Inter-American Development Bank
Social Progress Trust Fund.

Suggested Outline for the Presentation of a Settlement Project

A general outline for the presentation of settlement projects is given below which can be used as a guide and does not restrict the inclusion of additional information which could be useful in the project evaluation.

I. <u>Summary of the Project and the Request</u>

Present a brief highly summarized description of the characteristics and objectives of the project in order that the general basic information can be obtained by reading just a few pages. This summary should indicate: a) the number of families that will be benefitted; b) the zone in which the project will be carried out; c) the time required for its execution; d) the total cost of the project; e) the total amount of the loan requested; f) the manner in which the loan will be used; g) the dates on which the various sums will be needed; h) the terms of payment; i) the estimated amounts to be used in foreign and national currency; j) the name of the borrower and the organization carrying out the project, and k) capacity of the borrower to make contracts with the IDB.

II. <u>The Project</u>

A. <u>Objectives</u>

The objectives of the project should be described very precisely, with an indication of the amount of time necessary for achieving them.

B. <u>Natural Resources</u>

Description of the available resources and characteristics of the zone to be settled.

1. Area to be settled.

2. Climatic characteristics (rainfall, temperature, humidity, etc.); adverse or limiting conditions, such as frequency of floods, droughts, frosts, hail, etc.

3. Availability and quality of water, and depth of groundwater table.

4. Quality of the soils (include soil studies and maps of the area).

5. Topography.

6. Forest resources.

7. Agricultural exploitation potentials of the area.

C. Infrastructure

Indicate the infrastructure that already exists in the region such as roads, public facilities, etc. Infrastructural works needed for carrying out the project should be listed separately, under the following points:

1. Communication routes.

2. Educational, medical care, and hospital facilities.

3. Detailed list of infrastructural investments in farms and community facilities for which financing is requested. Community centers and their planning. (This information should be accompanied by plans, specifications, calculations, cost estimates, and technical justification for each of the works.

The investments should be classified as follows:

a. Investments in general infrastructure (roads, bridges, dams, canals, electric lines, etc.).

b. Investments in community facilities (schools, hospitals, markets, etc.).

c. Investments in agricultural units (housing, farm buildings, fences, wells, etc.).

D. Beneficiaries

1. Present population of the zone. Data should be given on the following:

a. Number of families presently established in the zone where the project is to be carried out.

b. Potential capacity of the zone to accommodate new families, and number of families planned to be established under the project.

2. Description of beneficiaries and criteria for selection:

a. Origin of the new families (renters, ejidatarios, sharecroppers, resident workers, rural laborers, small farm-holders, etc.).

b. Procedures to be followed in the selection of the new settlers.

3. Present income of the settlers.

4. Number of settlers to be established annually.

5. Current resources of settlers.

6. Types of land rights and titles that will be given to the settlers.

7. Methods followed in distributing the parcels of land (whether the title is to be paid for or free). If the title is paid for, indicate the price per hectare or manner in which the price is determined.

8. Plan of payment for the parcels by the beneficiaries. (Provisions should be taken to ensure that the payments made by beneficiaries for amortization and interest will not prevent them from obtaining adequate capital to develop their farms and improve their conditions.)

9. Grace period needed by the settlers and justification thereof.

E. Farming Units

1. Reasons for selecting the zone.

2. Existing crops and livestock; their characteristics, development, yields, sale prices, etc.

3. Type of operation proposed and studies on which it is based.

4. Size of farm units to be established and justification thereof.

5. General operating plan of the units and projection of yearly inputs and products of one of the typical agricultural units to be created under the project, up to the time it reaches full development.

6. Analysis of inputs of manpower needed for the operation of the unit.

7. Estimate of yearly investments and credit needs for each farm unit.

Note: Table E-1 gives an example of the yearly plan for operation of a farm unit in full production, with analyses of inputs and products and an estimate of yearly credit needs.

F. Financing Plan

1. Total cost of the project and distribution of funds by items.

2. List separately the investments that will be made:

   a. With the funds requested from the IDB.

b. With the contribution of the government, describing the government agencies or institutions participating, and

c. With contributions made by the beneficiaries.

3. List of investments to be reimbursed by the settlers.

4. Plan for amortization of and payment of interest on the loan requested.

5. Resources that will be available to meet amortization and interest service on the debt contracted with the IDB.

6. Budget of administrative and technical, educational, and medical assistance costs in the settlement zone, and manner in which they will be financed.

7. Financial projection of the project over a period of 10 to 15 years.

G. <u>Supplementary Information</u>

1. Relation of the project to the national development plans (insofar as possible, the project should be related to the overall development plans, if these exist).

2. Priority assigned to the project in the national development plans.

3. Government settlement programs. (Work done to date, total budget allocated for settlement during the past three years, number of families established, and area distributed.)

4. Detailed information on the agrarian structure of the country, particularly in the region where the project will be carried out.

5. Health conditions in the zone to be settled.

III. <u>Administrative and Technical Organization</u>

A. <u>Agency that will carry out the project</u>:

1. Its administrative and technical organization; availability of financial resources and technical staff; need for technical assistance to carry out the project, indicating types and estimated cost.

2. Relation of the agency that will carry out the project to the official agricultural extension, agricultural credit, and educational agencies, and so on, both national and regional.

3. Organizational chart of the institution and list of the professional and technical personnel in the main office and in the field offices, showing their branches of specialization.

Note: The request should be accompanied by appendixes giving full information on the agency requesting the loan, and/or the agency that will carry out the project, such as:

a. Law establishing the agency and a copy of the pertinent legislature or charter if available.

b. Balance sheets, statements of profit and loss, and budgets for the last three years, and statement of accounts.

c. Regulations, annual reports and other publications that provide further information on the organization.

B. Technical Assistance to the Beneficiaries

1. Organization of the agricultural extension service in the settlement centers.

2. Manner in which these services are provided to the beneficiaries, and systems of coordination with national organizations.

3. Annual technical assistance budget for the first three years of the program, origin of the funds, and plans for future maintenance.

C. Internal Organization of the Settlement

Internal administrative organization of the settlement centers. (The project should encourage local initiative and responsibility. Consequently, it should be oriented toward a gradual increase in the capacity of the farmers themselves for initiative, management, and control.)

D. Cooperatives

Indicate whether the program contemplates the establishment of a system of agricultural cooperatives. If this is the case, give a brief description of the type of cooperative to be established, its organization, administration, and operation.

E. Marketing

1. Study of the national and international markets, as the case may be, for the principal items of the proposed production program.

2. Storage facilities for agricultural products that already exist in the zone and in the country, and the possibility of use of these facilities by the beneficiaries of the project. Plans for expansion, improvement and management of storage facilities.

3. Plan for marketing the beneficiaries' products.

4. Are there any price control agencies for farm products in the country? If so, give a brief description and state their function in the marketing program.

IV. <u>Agricultural Credit</u>

1. Estimated needs for short-, medium-, and long-term credit. (State how credits will be used during the first years, specifying the items, amounts required, interest rates and other costs, guaranties and amortizations.)

2. Study of the beneficiaries' estimated capacity to pay to meet their short-, medium-, and long-term obligations.

3. Financing, organization, and administration of credit.

4. Plans available to provide settlers with equipment, tools and other supplies for agricultural production at reasonable prices.

V. <u>Social Justification of the Project</u>

Social benefits generated by the project:

1. Changes in the agrarian structure of the zone.

2. Reduction of population pressure.

3. New and better employment opportunities.

4. Measures tending to improve the conditions of salaried farm workers.

5. Number of landless rural workers who will receive land.

VI. <u>Economic Justification of the Project</u>

1. Income yield of the project.

2. Anticipated changes in present standards of living as a result of the project. Estimated income of beneficiaries before they are settled, and level of income that it is hoped they will attain through the project. Comparison of this income level with the average level in other economic sectors.

3. Increase in the area that will be devoted to farming.

4. Increase in agricultural productivity, including productivity per capita and per hectare, as well as yield of the various products.

5. Estimated present and future production in the area, by products.

6. Relation and contribution of the project to the economic development of the country (its effect on the balance of payments, of labor employment, better utilization of resources available, and the like).

7. Importance of the agricultural sector and level of national self-sufficiency in food production.

Comments

1. All information on the body of the project should be summarized as much as possible. However, when the importance of additional information justifies it, the necessary appendices should be added, giving all pertinent details.

2. A brief description of the institutional reforms that have been made or that are being undertaken in accordance with the Act of Bogota and the Declaration of Punta del Este, should be appended as supplementary information to the project.

3. In all cases in which various alternatives are presented for the solution of a problem one of them should be recommended with the pertinent technical and economic justification.

Table E-1

SUMMARY OF AN OPERATING PLAN OF AGRICULTURAL UNITS[a]

I. Land Use and Crop Production:

Crop or land use	Area (Has.)	Yield per ha.	Total production kg.	Consumption: On the farm kg.	Consumption: In the home kg.	Available for sale: Quantity	Available for sale: Value (US$)	Days of Work
Rice	3.0	1,500 kg.	4,500	100	200	4,200	500	255
Bananas	1.0	9 M.T.	9	3	1	5	52	60
Cassava	1.0	10 M.T.	10	5.5	0.5	4	53	65
Corn	1.0	1,600 kg.	1,600	600	300	700	18	40
Beans	0.5	700 kg.	350	-	100	250	12	30
Peanuts	0.5	1,000 kg.	500	150	50	300	75	40
Improved pastures	19.0	24 AUM	456	456	-	-	-	38
Vegetables	0.5	8 M.T.	1	1	2	1	50	50
House, sheds, roads, etc.	0.5	-	-	-	-	-	-	10
Forest reserves	3.0	-	-	-	-	-	-	2
Totals	30.0						760	590

Value of crops used in the home: US$ 190.00

a. To give an idea of the basic general information that is required in the application, in order to facilitate its evaluation, this gives an example of how this information should be presented. Even though values are stated in dollars, in each case the amounts should be given in the currency of the country presenting the request, showing the rate of exchange used. In indicating yields per hectare and the sales price per unit, the most common and representative figures of the region should be adopted. In the sales price per unit it should be indicated if it is at the farm, since, otherwise, it will be necessary to take into account the cost of transportation and other marketing costs. Whenever possible, supplementary technical information should be included, justifying the yields and sales prices that were used.

(Continue)

Table E-1 (Cont'd.)

II. Livestock Production:

Class	Inventory at the beginning of the year	Production during the year	Losses	Consumption in the home	Inventory at the end of the year	Available for sale		Days of Work
						No.	Value (US$)	
Bulls[1]	1	-	-	-	1	-	-	5
Cows	18	5	1	1	13	3	150	90
Young cows (2-3 yrs.)	6	6	1	1	6	-	-	24
Steers (2-3 yrs.)	6	6	-	-	6	6	350	24
Calves (1-2 yrs.)	13	13	1	-	13	-	-	26
Calves up to 1 yr.	14	14	1	-	14	-	-	42
Boars[1]	1	-	-	-	1	-	-	3
Hogs	-	22	2	2	-	18	300	44
Sows	2	1	1	-	2	-	-	10
Horses[1]	2	-	-	-	2	-	-	10
Fowl	30	50	10	40	30	-	-	10
Totals							800	288

Total animal units 43.35. Value of the livestock utilized in the home: US$173.00

(Conversion factors of animals to animal units: Bulls 1.25; Cows 1.00; Young Cows 0.80; Steers 0.80; Calves 0.50; Calves up to one year included with cows; Boars 0.30; Sows 0.25; Hogs 0.20; Mules of adult horses 1.00; Fowl 0.01)

1. Purchased whenever necessary--every two to three years.

(Continue)

Table E-1 (Cont'd.)

III. Production of Milk, Cheese, Eggs, etc.:

Product	Unit	Quantity	Consumed in the home	Sales: Quantity	Sales: Value (US$)	Days of Work
Milk (1 cow)	liter	500	500	-	-	10
Eggs (30 hens)	unit	3,000	1,500	1,500	62	10
Totals					62	20

Value of products consumed in the home: US$ 125.00

IV. Feeding Plan for Livestock:

Type of Livestock	Number of Animal Units	Pasture Needs per Animal Unit per Month	Grains	Concentrates and Minerals: Mixed Concentrates	Concentrates and Minerals: Minerals	Others (Tubers and Fruit)
Cattle	35.35	424	100 kg.	-	650 kg.	500 kg.
Swine	5.20	8	350 kg.	100 kg.	150 kg.	8,800 kg.
Horses	2.00	24	100 kg.	-	-	-
Fowls	0.80	-	650 kg.	100 kg.	50 kg.	200 kg.
Totals	43.35	456 AUM	650 kg.	200 kg.	850 kg.	9,500 kg.
Supplied by the farm		456 AUM	650 kg.	-	-	9,500 kg.
To be purchased		-	-	200 kg.	850 kg.	-
Cost of purchases US$		-	-	33	20	-

Total cost of feed purchased US$ 53.00

(Continue)

Table E-1 (Cont'd.)

V. Total Days of Work per Year for the Operation Planned (Tables I, II, III) 898 days

Supplied by the farmer and his family 720 days

Farm hands, hired 178 days

Cost of hired farm hands: (US$ 0.83 per day) US$ 148

VI. Annual Operating Cost in Cash (US$)

Seed purchased	7	Tools purchased	13
Feed for livestock	53	Transportation (personal trips)	42
Purchase of livestock (partial replacements)	83	Taxes	20
		Depreciation for improvements and machinery	92
Fertilizers (100 kg. per hectare cultivated)	133	Interest on debts	183
Pesticides	83	Other expenses	83
Medicine and veterinary services	83	Total farm costs	1,043
Maintenance of equipment	20	Living expenses, in cash	292
Hired farm hands	148	Total	1,335

VII. Summary of Income and Total Value of Production (US$)

Crop sales	760	Total cash income	1,622
Livestock sales	800	Value of products consumed in the home	488
Livestock products sales	62	Total value of farm production	2,110

(Continue)

Table E-1 (Cont'd.)

VIII. Estimate of Net Income Available to Pay Long-term Debts and for Savings:

Total cash income (US$)	1,622
Less Expenses for the Farm and Home (US$)	1,335
Net Cash Income (US$)	287

IX. Description of the Operation and Technological Level Assumed:

A. Mechanization: Animal-drawn equipment only. Two horses are included in the plan as draft animals, with the corresponding equipment.

B. Estimated yields: These are normal in the zone. It is planned to apply a very limited quantity of commercial fertilizers in view of the high price of these products. The estimated yields, per unit, can be obtained through the use of manure. If it were possible to supply commercial fertilizers at lower prices, the yields could increase considerably.

C. Financing: The projection of the development of this unit is based on the availability of suitable sources of credit for long-term financing of permanent installations, as well as sources for medium- and short-term credits for farm operations.

D. Market: This is based on the availability of passable roads for vehicles, as well as cooperative and official measures to organize market channels.

APPENDIX F

Six Maps

(See inside back cover)

APPENDIX G

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Table 2

SUMMARY OF LITHOLOGY, GEOMORPHOLOGY, HYDROLOGY, AND ENGINEERING AND ECONOMIC DATA OF GEOLOGIC FORMATIONS - GUAYAS BASIN, ECUADOR

Lithology		Geomorphology				Economic Data	
Formation	Description	Land form	Erosion characteristics	Hydrology	Engineering data	Mineral resources	Agriculture
Alluvium	Conglomerate, sand, silt and clay; includes some reworked ash. Constituents are rounded cobbles and boulders of fresh igneous rocks. Sands range from coarse to fine and contain a high percent of feldspar grains in various stages of decomposition. Unconsolidated.	Guayas Basin: a broad flood plain; coarse material near mountain front and major rivers; finer material in central plains; and fill in smaller valleys.	Frequently flooded, easily eroded; slow runoff due to generally low gradients; porous; internal drainage fair.	Shallow wells should yield adequate amounts for domestic and agricultural purposes. Large capacity deep wells could be drilled for irrigation in the Guayas plains.	Fair to good foundation stability; cut slopes unstable; requires confining or supporting structures. Easily excavated with hand tools; heavy equipment required to move large boulders near mountain front.	Near mountain front has been worked for placer gold in small concessions. Excellent source of gravel fill. Aggregate concrete or asphalt, sands require washing and screening. Silt and clay are used for ceramic tile, bricks and adobe blocks.	Good agricultural areas. Periodic flooding introduces fresh material.
	Conglomerates with lenses of coarse sand, silt, locally consolidated.	Western Upland Valleys: material is sand size or smaller; rare rock fragments. Western Andean area: stream beds are unconsolidated alluvium; incised and perched older Quaternary, semiconsolidated alluvium.	Easily eroded. Streams have very high gradients, large volume, wide velocity ranges.	Low-yield springs in steep road and stream cutbanks.	Semiconsolidated, stable in steep cuts but require retaining screens for loose boulders.	Local source of gravel fill, and concrete or asphalt aggregate. May contain undesirable amounts of pumice debris.	Suitable for agriculture only in broader valleys.
Cangagua	Ash and tuff, dense, medium brown-gray, homogeneous. Locally reworked by water in Inter-Andean Basin. Contains gravels and sands.	Smooth upland surfaces in mountains.	Easily eroded; forms steep "V" gullies; porous; permeable in high scarps; may form landslides as along major deeply incised rivers.	Soil very porous; does not retain water but may contain large amounts of water in buried basins or along bases of old channels.	When dry is fairly stable in steep slopes; semiconsolidated; tends to form natural vertical faces; easily disturbed by earthquakes; workable with hand tools.	Ash and cinder could be used in new lightweight cement block of high acoustic and thermal insulation value. K salts from leached areas precipitated along bedding planes; possible source of K; is widely used for adobe.	Rich agricultural soil but requires irrigation.
Progreso	Sandstone, shale, and siltstone. Semiconsolidated, locally iron-cemented; sandstone is medium to coarse grained, arkosic; plant fragments common; cross-bedded in large lenticular units 20-30 feet thick. Shale clayey, irregularly bedded; interbedded with sandstone and siltstone, very tuffaceous.	Cord. de Colonche. Maturely dissected hills up to 1,000 meters elevation with generally horizontal or gently dipping strata. Local thick sandstone beds form vertical to near-vertical scarps, as near Pedro Carbo.	Very porous, permeable; surface drainage rapid.	Shallow wells to sandstone lenses or beds may yield sufficient quantities of water for domestic and agricultural purposes.	Cut-slope stability fair in sandstone, poor to fair in siltstone and shale. Foundation stability fair to good but requires reinforcing across sandstone-shale interfaces; shale expansion sould be tested. Can be excavated with hand tools and light power equipment.	To date has not yielded commercial quantities of oil and gas. Shale used for adobe and low-grade tile. Heavy mineral and trace elements not known, should be studied.	Poor adaptability for agriculture due to highly dissected terrain. Does support most local crops (bananas, oranges, coffee, cacao).
Charapoto	Shale, clayey even-bedded, local limestone nodules and concretions; highly fractured, moderately indurated.	Low rounded foothills, as near Portoviejo.	Easily eroded; becomes sticky and plastic when moist. Relatively impermeable except along fractures.	Probably nil as moisture would tend to close fractures.	Very uniform composition, fair foundation stability; cut slopes stable 3:1; steeper cuts require reinforcing. Test for expansion.	Locally used for adobe. Clay composition not known.	Poor adaptability for agriculture.
Subibaja Dos Bocas Tosagua Onzole	Siltstone and shale. Siltstone, massive-bedded. Shale, thin-bedded, silty, locally tuffaceous.	Low rounded hills and gently sloping valley floors and heads of valleys. Maturely dissected.	Easily eroded to moderately resistant as silt constituents increase. Low porosity and permeability.	Low water capacity.	Low cut slope stability 3:1; fair foundation stability.	Locally used for adobe. Gas pockets reported in Dos Bocas in surface.	Poor to fair adaptability to agriculture.
San Mateo Socorro	Sandstone and shale crossbedded, coarse-grained, medium-grained; derived from erosion of granodiorite. Carbonaceous. Local conglomerates contain boulders of andesite, green slate (Callo Formation), gypsum partings on bedding of Socorro clay.	San Mateo limestone hills west of Portoviejo.	Moderately resistant to erosion; local FeO cement; porous and permeable; has good internal drainage.	Fair water reservoir capacity, but areal distribution is in arid zone.	Fairly stable in steep cuts, has good foundation stability. Can be worked with hand tools or light power equipment.	No data available	Poor adaptability for agriculture.

Cerro Callo	Volcanic tuff, sandy tuff, with $CaCo_3$, some silicified beds, silicified agglomerates.	Resistant caps on monoclinal cuesta along Cor. Colonche, Chongón and resistant covers on hills near Portoviejo.	Resistant to erosion, highly fractured; low porosity but permeable along fractures.	Poor water capacity, but local areas of highly fractured rock may yield water for domestic purposes.	Stable in steep cuts, has good foundation stability. May require blasting in large cuts, and use of medium to light power tools.	Used for riprap, fill, and road metal.	Poor adaptability for agriculture.
Piñon	Highly silicified or vitrified tuff, agglomerate and interbedded porphyritic diabase; very minor interbeds of shale and sandstone.	Resistant underbed of monoclinal cuesta of Cord. Colonche and Chongón.	Very resistant to erosion. Lavas subject to chemical weathering. Low porosity and permeability.	Poor water capacity; fractures, joints, or fault zones may contain sufficient quantities for domestic use.	Stable in steep slope unless highly altered by chemical weathering. Requires blasting and use of medium to heavy power tools.	Crushed stone for road metal and riprap.	Deep weathering produces soils which are fairly well adapted to agricultural use. The weathered zone retains water better than fresh rock.
San Eduardo	Limestone, fine- to medium-grained; farily pure $CaCO_3$, very low Mg. Locally silty; thin bedded, highly fractured.	Resistant capping bed of monoclinal cuesta of Cord. Colonche and Chongón.	Resistant to erosion; fair porosity and permeability along the fractures.	Poor to fair water capacity. Local solution cavities may yield large but unreliable amounts of water.	Stable in steep slopes or cuts. Requires blasting and use of medium to heavy power tools.	Largest source of lime for cement in Guayas Basin. Vast uncomputed reserves. Stratigraphic equivalent (?) also quarried for cement in Inter-Andean Basin at Calpi.	Produces fair soils for agriculture but, because of steep dip, slope in Cord. Colonche is unfavorable.
Pascuales	Diabase, highly fractured fine- to medium-grained.	Rounded residual hills projecting through alluvial plain.	Resistant to erosion; deep chemical weathering along fractures and joints.	Water capacity almost nil.	Excellent foundation stability, steep to vertical cuts. Requires blasting and power tools.	Crushed and weathered rock used for road metal. Local quartz veins reported to contain gold.	Deeply weathered soils are fertile but topography is unfavorable.
Intrusive igneous rocks	Diorite and syenite, green, fine-grained, highly fractured to massive.	Resistant foothills and high mountains along mountain front.	Resistant to erosion; decomposed chemically.	Low water capacity except along fractures and faults.	Excellent foundation and cut slope stability but, where rock is faulted, failures could result and crack asphalt pavement. Requires blasting and heavy power equipment.	Sulfide mineralization along faults and fractures has produced ore bodies, Cu, Au. Makes durable polished building stone, though hard to work. Pegmatitic veins should be studied as possible source of potassium.	Deeply weathered soils are fertile but topography is unfavorable. Used for local crops, banana, orange, coffee, cacao.

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Table 2
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