WATER RESOURCES ASSESSMENT OF EL SALVADOR

US Army Corps of Engineers
Mobile District &
Topographic Engineering Center

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Executive Summary

El Salvador is rich in hydrologic resources, although much of the surface water is contaminated and not developed for water supply. The major source of surface water contamination is from untreated domestic and industrial waste disposal, as most effluent is released into the rivers and coastal areas without any treatment. Recently enacted legislation requires new industries to treat effluent discharged into the nation's waterways. The Rio Acelhuate, the primary drainage system for San Salvador, is severely contaminated with heavy metals and domestic and industrial waste. This water is considered a biohazard, and the contamination so severe that it is rendered untreatable by reverse osmosis. The Rio Lempa, the largest and most important river in El Salvador, originates in Guatemala and flows through Honduras into El Salvador. Hydrologic data is critically needed on the Rio Lempa. Many gage sites have been damaged or destroyed, but additional new sites are also needed. There are three manmade reservoirs for hydropower generation on this river in El Salvador, providing about 60 percent of the country's power. The health of the reservoirs is a major national concern, threatened not only by chemical and biological pollution, but also by the large amount of sedimentation, created by deforestation, accumulating in the reservoirs. The sedimentation volumes in the Cerron Grande Reservoir are dangerously high – estimated to be as high as 7 million cubic meters per year – gravely impacting the health of the reservoir, not to mention the effects of the severely contaminated Rio Acelhuate, which flows directly into the Cerron Grande.

As a result of the polluted surface water, ground water is heavily relied upon for water supply. Sufficient supplies of fresh ground water are available throughout most of the country. The most abundant supplies are in the volcanic San Salvador Formation in the interior basin and on the lower slopes of most volcanoes. Important supplies are also available in the unconsolidated sediments of the coastal plain. Many shallow aquifers are, however, becoming contaminated from surface pollution, and deeper springs and wells are depended upon to provide potable water.

Twenty-five agencies share responsibility for overseeing the water resources of El Salvador. There is currently no mechanism for organizing the coordination of their efforts, which creates duplication and inefficient use of resources. A National Water Resources Management and Policy is recommended to strengthen coordination and therefore the overall effectiveness of the programs of the various agencies. Comprehensive watershed or basin management plans are needed to address deforestation and water resources management. Basic technical training, such as the HEC-2 program for calculating water surface profiles, would also be of great benefit. In addition, long-term national construction programs of wastewater treatment plants to eliminate the continued discharge of waste into the nation's waters would help reduce the amount of chemical and biological wastes contaminating the rivers, reservoirs, and ground water. A large-scale ground water exploration program, starting in the areas having the best aquifers, would increase the amount of potable water available for water supply.

Preface

In 1995 the U.S. Southern Command Engineer's Office commissioned the U.S. Army Corps of Engineers District in Mobile, Alabama, and the U.S. Army Corps of Engineers Topographic Engineering Center in Alexandria, Virginia, to conduct a water resources assessment of El Salvador. This assessment has two objectives: (1) to provide U.S. military planners with accurate information for planning various joint military training and humanitarian civic assistance engineer exercises such as the New Horizons series; and (2) to provide an analysis of the existing water resources of El Salvador and identify some opportunities available to the Government of El Salvador to maximize the use of these resources.

A team consisting of the undersigned water resources specialists from the U.S. Army Corps of Engineers Mobile District and the U.S. Army Topographic Engineering Center conducted the water resources investigations in April 1997 and subsequently prepared this report.

James O. Buckalew
Water Resources Engineer
Mobile District
Telephone: 251-690-3863
Fax: 251-690-2727
Email:
james.o.buckalew@sam.usace.army.mil

Robert B. Knowles, Hydrologist
Topographic Engineering Center
Telephone: 703-428-6737
Fax: 703-428-8176
Email: laura.c.dwyer@usace.army.mil

Laura Waite, Geologist
Report Manager
Mobile District
Telephone: 251-690-3480
Fax: 251-690-2674
Email: laura.e.waite@sam.usace.army.mil

Maurice James, P.E.
Hydrology and Hydraulic Design Specialist
Mobile District
Telephone: 251-690-3109
Fax: 251-690-3208
Email: maurice.james@sam.usace.army.mil

Jim Laprevote, Hydrologist
Topographic Engineering Center
Telephone: 703-428-6895
Fax: 703-428-8176
Email: laura.c.dwyer@usace.army.mil

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Many individuals in the public and private sectors were consulted and provided exceptional cooperation and support:

List of Officials Consulted

Name, Title	Agency/Firm	Address	Tel/Fax/Email
Ing. Rodolfo Montufar, General Director	EYCO Ingenieros S.A. de C.V.	Calle Arturo Ambrogi No. 124 Colonia Escalon San Salvador, El Salvador	tel. (503) 245-3148 fax. (503) 245-1313 email: ecoing@es.com.sv.
Sr. Gunnar Platais, Policy Advisor	Green Project/Abt Associates	81 Ave. Nte. & 11 C. Pte. #4216, Col. Escalon San Salvador, El Salvador	tel. (503) 263-3746 fax. (503) 263-3621 email: gplatais@es.com.sv
Srta. Amanda Ulloa, Policy Assistant for the Environment	Green Project/Abt Associates	Unavailable	(same as above) email: politica@es.com.sv
Ing. Leonardo Melos	Division of Recursos Naturales, Ministry of Agriculture and Livestock (MAG)	Unavailable	Unavailable
Ing. Guillermo Sol, General Director	Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL)	Unavailable	Unavailable
Ing. Pedro Miquel Estrada, President of Firm	EYCO, S.A. de C.V.	Unavailable	tel. (503)222-6430 fax. (503) 222-6803
Ing. Eduardo Castillo	Asociación Salvadoreña de Ingenieros y Arquitectos (ASIA)	Unavailable	Unavailable
Arq. Emilia Viera, Executive Director	Asociación Salvadoreña de Profesionales del Agua (ASPAGUA) / Asociación Salvadoreña de Ingenieros y Arquitectos (ASIA)	Unavailable	Unavailable
Ing. Mario Alberto Umana Reyes, Member	Asociación Salvadoreña de Ingenieros y Arquitectos (ASIS) / AIDIS	Unavailable	Unavailable
Lic. Rolando Sigifredo Noche Dimas, Vice President	Asociación Salvadoreña de Profesionales del Agua (ASPAGUA)	Unavailable	Unavailable
Sra. Dora Eugenia Gasteazoro Coen, Director of Communications	Salva Natura, Ecological Foundation of El Salvador	Pasaje Istmania 315 Entre 77 & 79 Avenida Norte Colonia Escalon San Salvador, El Salvador	tel. (503) 298-4001 fax. (503) 223-3620 email: salnatura@insatelsa.com
Ing. Ernesto Nosthas, Civil Engineer	Social Investment Fund (FIS)	55a Avenida Norte Edificio A Sala 42 San Salvador, El Salvador	Unavailable
Ing. Carlos Alberto Aguilar Molina, Agricultural Engineer	Secretaria Ejecutiva del Medio Ambiente (SEMA)	Urb. Buenos Aires, Pje. Mar de Plata No. 2 San Salvador, El Salvador	tel. (503) 260-3116 fax. (503) 260-3117 email: sema@gbm.net
Sr. Cesar R. Funes Abrego, Biologist	Secretaria Ejecutiva del Medio Ambiente (SEMA)	(same as above)	Unavailable
Sr. Carlos Araujo Campos, Department Supervisor	Ministry of Public Health, La Libertad (SALUD)	Unavailable	tel. (503) 228-0415, (503) 228-0529, (503) 228-0891 fax. (503) 228-0904
Ing. Fedor Paredes Sandoval, Engineer	Ministry of Public Health, La Libertad (SALUD)	Unavailable	Unavailable

List of Officials Consulted, Continued

Name, Title	Agency/Firm	Address	Tel/Fax/Email
Ing. Raul Rodriguez Rivera, Project Manager	Administración Nacional de Acueductos y Alcantarillados (ANDA)	2a. Avenida Sur No. 329 San Salvador, El Salvador	tel. (503) 271-4412
Ing. Carlos Augusta Perla, President	Administración Nacional de Acueductos y Alcantarillados (ANDA)	(same as above)	Unavailable
Dra. Ana Vilma Herrera, Technical Manager	La Fundacion Salvadoreña Para El Desarrollo Economica y Social (FUSADES), Laboratorio de Calidad Integral	Urb. y Blvd. Santa Elena, Antiguo Cuscatlan El Salvador	tel. (503) 278-9064, (503) 278-9065, (503) 278-3366 fax. (503) 278-9102 email: labfus@es.com.sv
Ing. Jose Ernesto Galvez, Project Manager	Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL)	Km 11.5 C. al Pto. de la Libertad Col. San Jose del Pino Santa Tecla	tel. (503) 228-1384 fax. (503) 228-1911
Ing. Jaime Eduardo Contreras Lemus, Hydrology Specialist	Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL)	Km 11.5 C. al Pto. de la Libertad Col. San Jose del Pino Santa Tecla	tel. (503) 228-1022 ext 268 & 269 fax. (503) 228-1911 email: cegiep@gbm.net
Ing. Victor Mendoza, Manager	Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL)	Unavailable	Unavailable
Lic. Miguel Eduardo Araujo, Economic Studies Manager	La Fundacion Salvadoreña Para El Desarrollo Economica y Social (FUSADES) / Consejo Empresarial Salvadoreño Para El Desarrollo Sostenible (CEDES)	(office near embassy)	email: codesnet@es.com.sv

List of Agencies Contacted

Agency	Acronym	Area of Responsibility
Administración Nacional de Acueductos y Alcantarillados	ANDA	National Administration on Aqueducts and Sewerage in charge of water supply, sewage disposal, and development of water resources.
Asociación Salvadoreña de Ingenieros y Arquitectos	ASIS	Salvadoran Association of Engineers and Architects, a non-government organization, providing training and technical assistance to communities on potable water and health issues.
Asociación Salvadoreña de Profesionales del Agua	ASPAGUA	Salvadoran Association of Water Professionals, a non-government organization, providing training and technical assistance to communities and designs potable water and health projects for communities.
Consejo Empresarial Salvadoreño Para El Desarrollo Sostenible	CEDES	Salvadoran Business Council for Sustainable Development, a non-government organization, promoting sustainable development aimed at protecting natural resources.
Comision Ejecutiva Hidroelectrica del Rio Lempa	CEL	Executive Commission on Hydropower for the Lempa River, an agency overseeing energy generation and distribution.
Fondo de Inversion Social	FIS	Social Investment Fund, promotes funds and provides water and other basic services for impoverished communities.
La Fundacion Salvadoreña Para El Desarrollo Economica y Social	FUSADES	Salvadoran Foundation for Social and Economic Development with more than 300 business owners supporting environmentally sustainable development and supporting development of a national water policy and privatization of water supply.
Instituto Geografico Nacional	IGN	National Geographic Institute, a national mapping institute.
Ministry of Agriculture and Livestock	MAG	Ministry of Agriculture and Livestock overseeing agriculture, forests, and wildlife resources.
Secretaria Ejecutiva del Medio Ambiente	SEMA	Executive Secretary of the Environment providing technical assistance to other agencies on water resources and environment issues.
EYCO	EYCO	A private engineering firm specializing in planning and development of water resources.
Ministerio de Salud Publica y Asistencia Social	MSPAS y SALUD	Provides technical assistance to communities on potable water and health related issues.

List of Acronyms and Abbreviations

Acronyms

ANDA	National Administration on Aqueducts and Sewerage
ASIA	Salvadoran Association of Engineers and Architects
ASPAGUA	The Salvadoran Association of Water Professionals
CARE	Cooperative for American Relief to Everywhere
CEDES	Salvadoran Business Council for Sustainable Development
CEL	Executive Commission on Hydropower for the Lempa River
COEN	National Emergency Management Agency
EYCO	A private engineering firm specializing in planning and development of water resources
FIS	Social Investment Fund
GDP	Gross Domestic Product
HEC	U.S. Army Corps of Engineers, Hydrologic Engineering Center
FUSADES	The Salvadoran Foundation for Social and Economic Development
IGN	National Geographic Institute
MSPAS	Ministry of Public Health and Social Assistance (also referred to as SALUD)
MAG	Ministry of Agriculture and Livestock
NGO	Non-Government Organization
SALUD	Ministry of Public Health and Social Assistance (also referred to as MSPAS)
SEMA	Executive Secretary of the Environment
USSOUTHCOM	U.S. Southern Command
USACE	U.S. Army Corps of Engineers (also referred to as Corps)
USAID	U.S. Agency for International Development

Abbreviations

^{o}F	degrees Fahrenheit
^{o}C	degrees Celsius
$CaCO_3$	calcium carbonate
DDT	dichlorodiphenyl trichloroethane
ft	feet
gal/d/ft	gallons per day per foot
gal/min	gallons per minute
GWh	gigawatthours
km	kilometers
km^2	square kilometers
kW	kilowatts
L/min	liters per minute
m	meters
mg/L	milligrams per liter
mi	miles
mi^2	square miles
mm	millimeters
m^2/d	square meters per day
m^3/s	cubic meters per second
MW	megawatts
Mm^3	million cubic meters
NaCl	sodium chloride
pH	hydrogen-ion concentration
PVC	polyvinyl chloride
T	transmissivity
TDS	total dissolved solids

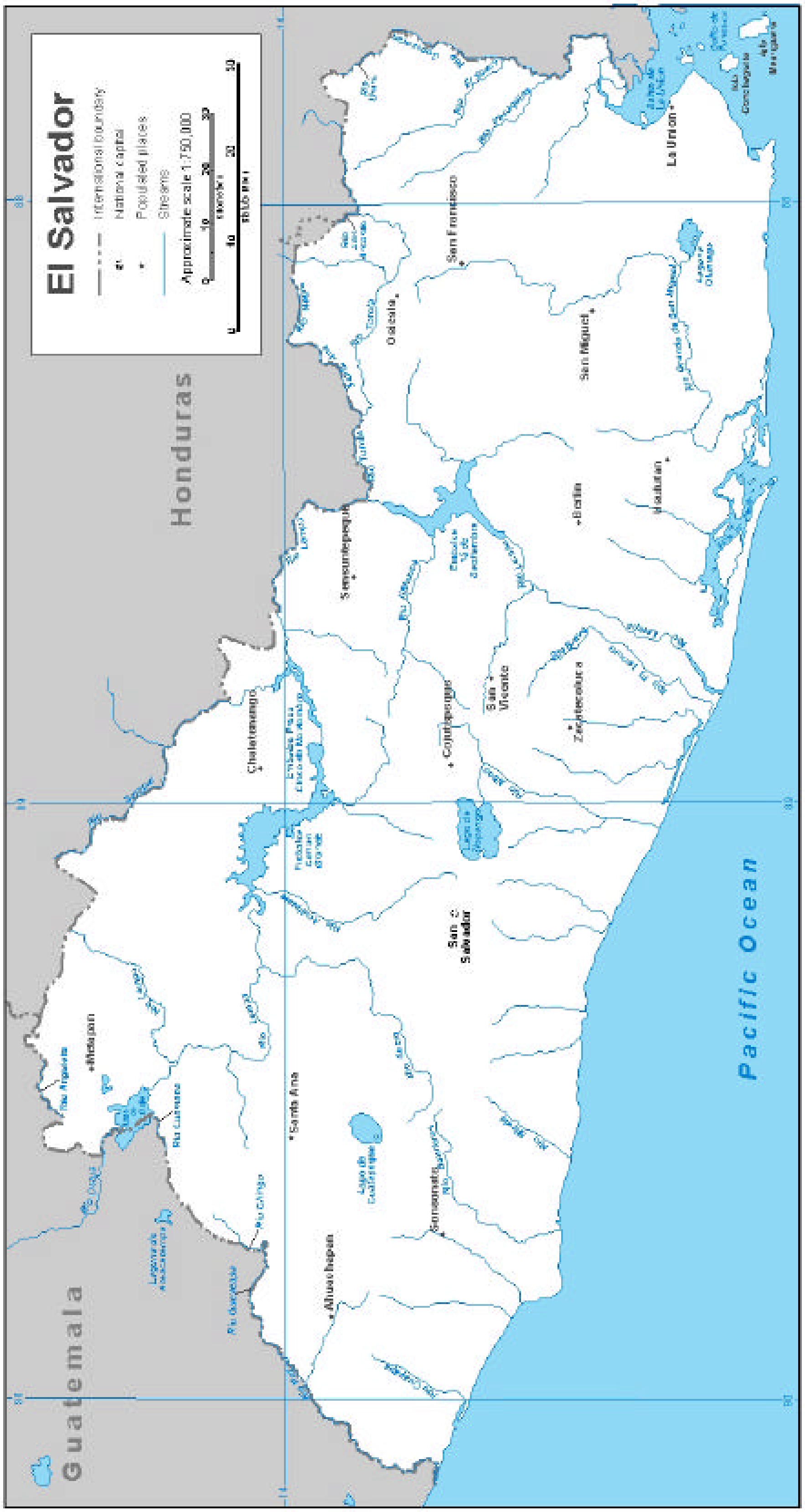

Figure 1. Country Map

I. Introduction

The gift of water nourishes and sustains all living things. At least 400 million people in the world live in regions with severe water shortages. By the year 2050, it is expected to be 4 billion people. The projected short supply of usable potable water could result in the most devastating natural disaster since history has been accurately recorded, unless something is done to stop it. Twenty-two countries are dependent on the flow of water from other nations for much of their supply, a dependency which can lead to friction, escalating tensions, or worse. El Salvador's most important river, the Rio Lempa, originates in Guatemala, and flows through Honduras into El Salvador. More than a dozen nations obtain most of their water from rivers that cross the borders of neighboring countries which can be viewed as hostile. Even when nations are on the best of terms, there are serious disagreements over water-sharing issues.

The purpose of this assessment is to document the general overall water resources situation in El Salvador. This work involved describing the existing major water resources, identifying special water resources needs and opportunities, documenting ongoing and planned water resources development activities, and suggesting practicable approaches to short- and long-term water resources development. This assessment is the product of an in-country information-gathering trip, plus information obtained in the U.S. on the part of four water resources professionals. The scope was confined to a 'professional opinion' given the size of the country and the host of technical reports available on the various aspects of El Salvador's water resources.

This information can be used to support current and potential future investments in managing the country's water resources and to assist military planners during troop engineering exercise and theater engagement planning. The color surface and ground water graphics, complemented by the tables in Appendix A, should be useful to water planners as overviews of available water resources on a country scale. The surface water graphic divides the country into surface water regions, based on water quantities available. The ground water graphic divides the country into regions with similar ground water characteristics.

In addition to assisting the military planner, this assessment can aid the host nation by highlighting its critical need areas, which in turn, serves to support potential water resources development, preservation, and enhancement funding programs. Highlighted deficiencies include the lack of wastewater treatment plants and discharge-effluent laws which are major causes of the severely contaminated surface water. The effects of deforestation have contributed tremendously to the decline in the health of the country's reservoirs, which generates most of the country's power. Watershed management plans should be enacted to control deforestation and to manage water resources. Ground water supplies most of the potable water for the country because the surface water is contaminated, in many cases, beyond treatment. Large-scale national well-drilling programs are recommended, particularly starting in the map unit 1 areas displayed graphically in Appendix A, figure A-2.

Twenty-five agencies share the responsibility for overseeing the water resources of El Salvador. As part of the preparation of this assessment, the U.S. Army Corps of Engineers met with many of these agencies which are listed on page v. Most of these agencies conduct their missions with little or no coordination with other agencies, which creates duplication and inefficient use of resources.

II. Country Profile

A. Geography

El Salvador, with its 21,041 square kilometers of territory, is slightly smaller than the U.S. state of Massachusetts and is the smallest Central American nation. El Salvador shares a 203-kilometer border with Guatemala to the west, a 342-kilometer border with Honduras to the north and east, and has a 320-kilometer Pacific coastline to the south. See figures 1 and 2 for general geographic information.

El Salvador can be divided into three major physical regions: a tropical coastal belt on the Pacific, a central upland area of valleys and plateaus, and a mountainous north. The coastal region is an area of fertile soils with an average width of 16 kilometers (10 miles), that widens to a maximum width of 32 kilometers (20 miles) near the Golfo de Fonseca. The central valley region averages about 600 meters (2,000 feet) in elevation and comprises the upland valley between two mountain ranges. Most of the population is concentrated in this region, where the major cities of San Salvador (the capital), Santa Ana, San Miguel, Sonsonate, and San Vicente are located. The northern region consists of the Rio Lempa valley and a northern mountain range. This region, which was once covered with forest, is now arid and semi-barren caused by deforestation and damaging agricultural practices. As a result, this area is the least populated with little farming or other development. More than 20 active volcanoes are in the north, and nearly all of the country's soil is volcanic. El Salvador is also subject to earthquakes, such as those that devastated San Salvador in 1965 and 1986. The Rio Lempa, El Salvador's main river, is not navigable by large vessels.

Figure 2. Vicinity Map

Rainfall is concentrated from May to October, and distribution varies from about 150 centimeters (59 inches) in the coastal plains to as much as 230 centimeters (90 inches) in the mountain ranges. Temperatures average 23 degrees Celsius (73 degrees Fahrenheit) in the capital but are much higher along the coast.

B. Population Distribution

With a 1997 population estimated at 5,908,560, El Salvador is the most populous country in Central America with an annual growth rate of 1.8 percent (1996 estimate). Most of the population is concentrated in the central region, especially in large cities such as San Salvador and Santa Ana. This region is also home to most of the industries in El Salvador and has the most fertile farmland. (See table 1. Population Distribution.)

Table 1. Population Distribution

Department	Population (estimates mid-1997)	Capital	Area (km^2)
San Miguel	455,270	San Miguel	2,077
Morazan	170,861	San Francisco	1,447
La Union	280,298	La Union	2,074
Usulutan	333,077	Usulutan	2,130
San Vicente	155,265	San Vicente	1,184
Cabanas	150,173	Sensuntepeque	1,104
Cuscatlan	196,413	Cojutepeque	756
Chalatenango	192,601	Chalatenango	2,017
La Paz	278,465	Zacatecoluca	1,224
La Libertad	622,509	Nueva San Salvador	1,653
San Salvador	1,831,532	San Salvador	886
Sonsonate	419,019	Sonsonate	1,226
Santa Ana	522,139	Santa Ana	2,023
Ahuachapan	300,938	Ahuachapan	1,240
TOTAL	**5,908,560**		**21,041**

1997, Direccion General de Estadistica y Censos.

C. Economy

The agricultural sector of the economy employs almost 40 percent of the labor force and accounts for about 25 percent of the gross domestic product (GDP) and for about 66 percent of total exports. The other primary economic sectors, along with the percentages of the labor force they employ, are: commerce (16 percent), manufacturing (15 percent), government (13 percent), financial services (9 percent), transportation (6 percent), and other (1 percent). The chief agricultural export products are coffee, sugar, and farm-raised shrimp. Coffee is the major commercial crop, accounting for 45 percent of total export earnings. Other agricultural products include pineapples, melons, vegetables, cut flowers, cattle, cotton, and dairy products. The manufacturing sector, based largely on food and beverage processing, along with petroleum, tobacco, chemicals, textiles, and furniture, accounts for 18 percent of the GDP.

D. Flood Control

National Emergency Management Agency (COEN) is responsible for responding to natural disasters but they do not conduct risk studies for flooding. Most flooding is associated with the Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL) releases from their reservoirs. Detailed studies on flooding and flood control projects are not available.

E. Legislative Framework

New laws in the El Salvador Congress, if enacted, would make the Secretaria Ejecutiva del Medio Ambiente (SEMA) responsible for the national environmental regulatory policy and give it the power necessary to enforce compliance. Current land use regulations rest with the Administracion Nacional de Acueductos y Alcantarillados (ANDA), but these regulations lack the necessary enforcement tools. Although there is a general lack of enforcement, laws for regulating discharge of domestic and industrial wastes exist, but only for new industries.

III. Current Uses of Water

A. Water Supply

Ground water is the major source of potable water for domestic use because surface water is heavily contaminated by both industrial and domestic wastes. Potable ground water is available in most departments; however, there are areas in the mountainous north-central region where ground water is becoming less plentiful. Officials interviewed attribute this reduction in available ground water to deforestation and damaging agricultural practices. Deforestation strips the natural vegetation from the hillsides which increases the rainfall runoff, not allowing sufficient time for the rain to soak into the soil and recharge the aquifers. Along the coastal regions and near the river deltas, saltwater intrusion into the aquifers is a problem. The greatest need for reliable potable water supplies are in the department of Morazon near the Honduran border and in the northern mountainous regions of El Salvador. Ministerio de Salud Publica y Asistencia Social (MSPAS) has a program to install hand pumps down to depths of 12 meters (40 feet) in rural communities with a goal of one pump for every five families.

1. Domestic Uses and Needs

ANDA is the agency primarily responsible for developing and maintaining potable water systems for both urban and rural areas. Currently ANDA oversees water systems in about 177 towns and villages. The development of water supply projects for rural areas involves several agencies besides ANDA. One such agency is the Fondo de Inversion Social de El Salvador (FIS) that supplies the materials and expertise for the construction of ground water and surface water systems. While ground water systems are more common, the surface water systems are generally constructed in areas where ground water is difficult to locate and where access exists to small uncontaminated streams. MSPAS is responsible for operating and maintaining the rural water systems, but they lack the necessary resources to make repairs, train operators, or upgrade systems. In addition to the water systems constructed by the Government, many rural communities construct their own systems. In most cases, little is known about these systems; however, officials interviewed indicated that few of the systems function for more than 5 years, primarily because of poor maintenance and equipment failure.

The city of San Salvador withdraws about 1.5 cubic meters per second from the Rio Lempa, with the rest of its water coming from wells within a 15-kilometer radius of the city. The departments of Sonsonate (west of San Salvador), Usulutan, and San Miguel (east of San Salvador) are rich in surface and ground water resources. The area near the city of Quezaltepeque (northwest of San Salvador) consists of volcanic formations that have plentiful ground water supplies at varying depths. Excessive mineral concentrations in the ground water, especially from iron, are common in the region.

2. Industrial/Commercial Uses and Needs

Minimal data exist on water use by the industrial sector. Sugar-cane processing is a major industrial use of water. According to SEMA, a 35-year-old sugar-processing plant that withdrew 38 cubic meters (10,000 gallons) of water per minute from an adjacent river, recently installed a recirculation system to reduce river withdrawals. Improvements like these to reduce the requirements for water are needed by many industries, especially the older inefficient ones, but financing is difficult.

3. Agricultural Uses and Needs

Officials with the Ministry of Agriculture and Livestock (MAG) estimated the total number of hectares under irrigation at 20,000. Most of the established irrigation projects are privately owned and require the users to reimburse the systems owners based on the amount of water used. According to the Asociación Salvadoreña de Profesionales del Agua (ASPAGUA) officials interviewed, these systems have high losses that can be attributed to a lack of proper maintenance and technical support.

B. Hydropower

CEL is responsible for the El Salvadoran electrical energy system. CEL's primary mission is the development of the Rio Lempa for hydropower. Currently, three manmade reservoirs for hydropower generation are on the Rio Lempa. They are the Embalse Cerron Grande, the Embalse Presa Cinco (5) de Noviembre, and the Embalse Quince (15) de Septiembre (see figure A-1 in Appendix A). These three hydropower plants provide almost 400 megawatts or about 60 percent of El Salvador's total capacity. The rest of the power needs of El Salvador are met using a combination of small hydropower, geothermal, and fossil fuel plants. According to the CEL officials interviewed, plans are being finalized to expand the capacities of the Embalse Presa Cinco (5) de Noviembre and the Embalse Cerron Grande by 120 megawatts and 67 megawatts, respectively. The Cerron Grande project, constructed in 1976, is the only regulated hydropower project on the Rio Lempa. It was designed so that water can be collected during the wet season and released during dry periods to supplement the two plants downstream. The current hydropower capacity for El Salvador is shown in table 2.

Table 2. Hydropower Plants

Project	Current Capacity (kW)
Cerron Grande	135.0
Presa Cinco de Noviembre	81.4
Quince de Septiembre	180.0
Other Hydropower	
Geothermal	208.5
Fossil Fuel	56.6
Total capacity	**661.5**

The overall health of the CEL reservoirs is a concern to the CEL officials interviewed. The Embalse Cerron Grande receives large amounts of domestic and industrial wastes from San Salvador via the Rio Acelhuate. The Rio Lempa also contributes significant amounts of domestic and industrial wastes along with sediments from deforested areas. Estimates of sedimentation volumes range as high as 7 million cubic meters per year into the Cerron Grande reservoir. These combined sources threaten the overall health and sustainability of the reservoirs.

The CEL officials are interested in bathymetric survey technology, instrumentation equipment technology, and methods to control aquatic plants. The need for additional hydrometric gage sites within the Rio Lempa basin was also mentioned in discussions. Two reasons for the lack of hydrologic data sites are; (1) many of the gages were either damaged or destroyed during the civil war; and (2) funds are needed to repair, replace, or establish new sites. The establishment of new gage sites is further complicated because the Rio Lempa basin is located in three countries, originating in Guatemala and flowing through Honduras before entering El Salvador. Currently there are no multinational agreements on the sharing of data or the installation of hydrometric stations. There is a critical need for hard data, both as a basis for decision-making and as an analytical tool.

C. Waterway Transportation

Commercial navigation along the rivers of El Salvador is almost nonexistent. The country's largest river, Rio Lempa, connects a network of over 150 smaller streams that serve local transportation and commerce. The river is navigable only through short disconnected reaches by small shallow draft vessels.

IV. Existing Water Resources

El Salvador relies heavily upon ground water sources for its water supply because surface water is generally severely polluted and therefore not normally developed for water supply. In urban areas, approximately 86 percent of the population has access to water supply services and 84 percent to sanitation. In rural areas, approximately 15 percent have access to water supply services and 51 percent to sanitation. Water supply for basic human needs is a severe problem. Waterborne diseases such as dysentery (often caused by contaminated water) are the major cause of infant mortality in the country.

Sufficient supplies of fresh potable ground water, derived mainly from deeper wells and springs, are available throughout most of El Salvador. Shallow wells are more likely to be contaminated.

A. Surface Water Resources

Although surface water resources are abundant, they are unequally distributed, highly seasonal, and generally polluted. During the dry season from December to April, many streams cease to flow.

1. Precipitation and Climate

The dominant tropical climate results in an average annual precipitation of 183 centimeters (72 inches). Precipitation increases with elevation, varying from about 150 centimeters (59 inches) in the coastal plain to as much as 230 centimeters (90 inches) in the mountain ranges. About 95 percent of the rainfall occurs from May to October with frequent and severe droughts occurring during the drier months. El Salvador has a dry season, a wet season, a transitional wet-to-dry season, and a transitional dry-to-wet season. River flows are high in the wet season from June to October and low during the dry season from December to April. Wet-to-dry and dry-to-wet transitional seasons occur in May and November. The country's dense vegetation and hot tropical climate create high evapotranspiration rates year-round.

2. River Basins

The country has four large river basins and seven smaller river basins that drain the Pacific Coastal Cordillera. The four large river basins are the Rio Lempa basin, the Rio Goascoran basin, the Rio Grande de San Miguel basin, and the Rio Paz basin. Table 3 contains information on the four major river basins. The seven smaller basins are: (1) the coastal area between the Rio Cara Sucia and Rio Copinula; (2) the coastal area between the Rio Sensunapan and Rio Banderas; (3) the coastal area between the Rio Pululuya and Rio Comalapa; (4) the Rio Jiboa basin; (5) the coastal area between the Rio Jalponga and Rio El Guayabo; (6) the coastal area between the Rio El Potrero and Rio El Molino; and (7) the coastal area between the Rio Grande de San Miguel and Rio Sirama. All rivers in El Salvador eventually discharge into the Pacific Ocean. During a normal year, total surface water runoff from El Salvador to the Pacific Ocean averages 19 million cubic meters. See figure A-1.

Table 3. Major Drainage Basins

Number (see Fig. A-1 in Appendix A)	River Name	Receiving Body	Drainage Area (km^2) [1]	Total Annual Precipitation (m^3/s)	Annual Discharge (m^3/s)
1	Rio Lempa	Pacific Ocean	10,255	33,320	7,071
2	Rio Goascoran	Pacific Ocean	1,315	5,660	1,040
3	Rio Grande de San Miguel	Pacific Ocean	2,250	3,741	740
4	Rio Paz	Pacific Ocean	929	3,050	535
TOTAL			**14,749**	**45,771**	**9,386**

[1]Area within El Salvador.

3. Rio Lempa and its Reservoirs

The Rio Lempa is the largest and most important river in El Salvador with its basin covering an area of 18,246 square kilometers(km^2). Of this area, 10,255 km^2 are in El Salvador (about 49 percent of El Salvador territory), 5,696 km^2 are in Honduras, and 2,295 km^2 are in Guatemala. The Rio Lempa is the largest river system in Central America with its most important water use being for hydroelectric power. (See Hydropower chapter in Section III.)

As mentioned previously, there are three significant manmade reservoirs on the Rio Lempa which store enormous quantities of water for hydroelectric power generation. They are the Embalse Cerron Grande (135 km^2 surface area), Embalse Presa Cinco de Noviembre (20 km^2 surface area), and Embalse Quince de Septiembre (also called Embalse del San Lorenzo) (35 km^2 surface area). In addition, the Embalse del Guajoyo is a small reservoir on the Rio Desague in northwestern El Salvador that is used for hydropower. Discharge from the reservoirs controls the flow of the Rio Lempa. The average flow of the Rio Lempa is about 153 cubic meters per second (m^3/s) from the Embalse Cerron Grande reservoir, about 197 m^3/s from the Embalse Presa Cinco de Noviembre reservoir, about 329 m^3/s at the Rio Torola confluence, and about 362 m^3/s at the Cuscatlan bridge on the Pan American Highway. The Rio Lempa receives domestic and industrial wastes from population centers along its western margin and a high concentration of sediments from deforested zones along the eastern margin. These combined sources of contamination have polluted the Rio Lempa throughout El Salvador.

B. Ground Water Resources

Sufficient supplies of fresh ground water are available throughout most of El Salvador with springs and deeper wells providing the most reliable and important sources of ground water for domestic, municipal, agricultural, and industrial water supplies.

Although ground water is generally safer than untreated surface water supplies, many shallow aquifers are becoming biologically contaminated, primarily due to improper waste disposal. To understand how ground water hydrogeology works and where the most likely sources of water may be located, a short aquifer definition and aquifer characteristics are presented, followed by specific country attributes.

1. Aquifer Definition and Characteristics

Ground water supplies are developed from aquifers, which are saturated beds, formations, or group of formations which yield water in sufficient quantities to be economically useful. To be an aquifer, a geologic formation must contain pores or open spaces (interstices) that are filled with water and these interstices must be large enough to transmit water toward wells at a useful rate. An aquifer may be imagined as a huge natural reservoir or system of reservoirs in rock whose capacity is the total volume of interstices that are filled with water. Ground water may be found in one continuous body or in several distinct rock or sediment layers within the borehole, at any one location. It exists in many types of geologic environments, such as intergrain pores in unconsolidated sand and gravel, cooling fractures in basalts, solution cavities in limestone, and systematic joints and fractures in metamorphic and igneous rock, to name a few. Unfortunately, rock masses are rarely homogeneous and adjacent rock types may vary significantly in their ability to hold water. In certain rock masses, such as some types of consolidated sediments and volcanic rock, water cannot flow, for the most part, through the mass; the only water flow sufficient to produce usable quantities of water may be through the fractures or joints in the rock. Therefore, if a borehole is drilled in a particular location and the underlying rock formation (bedrock) is too compact (consolidated with little or no primary permeability) to transmit water through the pore spaces and the bedrock is not fractured, then little or no water will be produced. On the other hand, if a borehole is drilled at a location where the bedrock is compact and the rock is highly fractured with water flowing through the fractures, then the borehole could yield sufficient water to be economically useful.

Since it is difficult or impossible to predict precise locations that will have fractures in the bedrock, photographic analysis can be employed to assist in selecting more suitable well site locations. Other methods are available but are generally more expensive. Geologists use aerial photography in combination with other information sources to map lithology, faults, fracture traces, and other features which aid in well site selection. In hard rock, those wells sited on fractures and especially on fracture intersections generally have the highest yields. Correctly locating a well on a fracture may not only make the difference between producing high versus low water yields, but potentially the difference between producing some water versus no water at all. On-site verification of probable fractures further increases the chances of siting successful wells.

Transmissivity (T) is a property that describes aquifers. T is a hydraulic characteristic of an aquifer that indicates the rate water will move through a unit width of an aquifer under a unit hydraulic gradient in square meters per day (m^2/d) (or gallons per day per foot). Aquifers with T values less than 12 m^2/d can supply water to domestic wells; for T values greater than 120 m^2/d, the aquifers are adequate for municipal, industrial, and irrigation wells.

Recharge rates also affect how productive aquifers are. Most ground water recharge occurs in areas where surface soils are coarse, or where unaltered volcanics are exposed at the surface, such as on the upper flanks of volcanoes. Some recharge, mostly at the beginning of the wet season, also occurs in unconsolidated sediments in the interior valley and along streams. The high recharge in volcanic rocks accounts for the very large yields often produced. Unaltered exposed lava flows can absorb 30 percent of precipitation, while the more permeable scoria basalts can absorb up to 50 percent. Unconsolidated sediments also have good recharge rates, absorbing from 5 to 20 percent of available precipitation.

Overall, the water table surface is analogous to but considerably flatter than the topography of the land surface. Ground water elevations are typically only slightly higher than the elevation of the nearest surface water body within the same drainage basin. Therefore, the depth to water is greatest near drainage divides and in areas of high relief. In El Salvador, during the dry season from November to April, the water table drops significantly and is marked by the drying up of many smaller surface water bodies fed by ground water. The drop can be estimated based on the land elevation, on the distance from the nearest perennial stream or lake, and on the permeability of the aquifer. Areas that have the largest drop in the water table during the dry season are those that are high in elevation far from perennial streams and consisting of fractured material. In general, some of these conditions can be applied to calculate the amount of drawdown to be expected when wells are pumped. In the coastal plain and interior valleys where relief is low, localized declines in the water table may be significant during the dry season because of increased pumping to irrigate crops.

2. El Salvador Hydrogeology

Most aquifers in El Salvador are formed from the lava flows and pyroclastics of Middle Tertiary to Recent age that dominate the country. Important aquifers are the San Salvador Formation, the Cuscatlan Formation, volcanics older than the San Salvador and Cuscatlan Formations, and unconsolidated alluvial aquifers. In general, the best volcanic aquifers are in the youngest volcanic layers, such as the upper layers of the San Salvador Formation, with the most accessible high-yielding aquifers being located in the unconsolidated alluvial aquifers.

Deeper water wells and springs are heavily relied upon to provide water to El Salvador. Though ground water quality is generally good, poor quality water is likely to be found in coastal areas, near geothermal areas, in shallow aquifers and near populated areas.

For El Salvador, steel casing is recommended throughout the country. Steel casing is used exclusively for all water wells constructed by ANDA because of seismic activity and preferred well-cleaning methods. Wells completed with other types of casing materials may suffer excessive damage or deformation during seismic events.

a. San Salvador Formation

The San Salvador Formation, Upper Pleistocene to Recent age, is the youngest volcanic formation in the country, and is concentrated in the interior basins and valleys in the western and eastern sections of the country. Aquifers in this formation are composed of fractured lava flows, sedimentary deposits, and accumulations of uncompacted pyroclastics. Ground water occurs in layers of alluvium and pyroclastics between lava flows, along bedding planes, and in fracture zones within the individual lava flows. The upper layers of the formation are the best aquifers and commonly consist of fractured or brecciated lava flows and coarse-grained pyroclastics. The most productive aquifers are composed of scoria basalts found in localized deposits on the slopes of the numerous volcanoes in the country. Scoria basalts are extremely permeable. High recharge in volcanic rocks accounts for the very large yields often produced. Unaltered lava flows exposed on the surface can absorb 30 percent of precipitation, while the more permeable scoria basalts can absorb up to 50 percent. T is typically 100 m^2/d (8,000 gallons per day per foot). The lower layers of the San Salvador Formation, though not as permeable as the upper layers, have aquifers that yield moderate amounts of water. Some areas of the San Salvador Formation that are not as productive, exist on the steeper upper slopes of volcanoes, because these areas are generally above the regional ground water table and are not, therefore, suitable locations for wells.

b. Cuscatlan Formation

The Cuscatlan Formation, Lower Pleistocene age, is older than the San Salvador Formation and covers large areas of the interior basins and valleys in the central part of the country. In many areas, it underlies the San Salvador Formation. Transmissivities are generally less than 100 m^2/d, less than the San Salvador Formation, but good for high-yielding domestic wells. The Cuscatlan forms significant aquifers, though not as productive as those of the San Salvador Formation.

c. Older Volcanics

Volcanic rocks older than the San Salvador and Cuscatlan Formations, of Pliocene and older age, are also present in El Salvador, but these rocks tend to be weathered, compacted, and relatively impermeable. In most areas, they form an impermeable basement upon which the aquifers of the younger formations rest. Where these older volcanics are exposed on the surface, they may be marginally productive along open, mostly vertical fractures in interflow alluvial deposits between individual lava flows or in pyroclastic beds. A layer of relatively impermeable clay covers volcanics older than the San Salvador Formation in many areas. This overlying clay tends to inhibit ground water recharge to the underlying volcanics, which is one of the reasons some of the older volcanics are not as productive as younger volcanics. These older volcanic rocks also tend to be less fractured than the younger ones which reduces the productivity. They also have lower overall transmissivities, usually less than 10 m^2/d, good for domestic wells only. However, if fractures are not encountered during drilling, wells may be dry.

d. Alluvial Aquifers
The most accessible aquifers that yield moderate to large quantities of ground water are unconsolidated coastal plain aquifers and alluvial aquifers in the valley bottoms of perennial streams. The coastal plain aquifers thicken toward the ocean where they are more than 1,500 meters thick. The alluvial aquifers outside the coastal plain along large perennial streams are usually less than 30 meters thick. Unconsolidated alluvium has good recharge rates, absorbing from 5 to 20 percent of available precipitation and with T values ranging between 200 and 500 m^2/d, which can support municipal and irrigation wells. However, caution should be exercised as water, from shallow depths, in these types of aquifers is also highly susceptible to contamination that is prevalent throughout El Salvador.

C. Water Quality

Water pollution caused by human waste, agro-industrial residues, and other solid wastes, is a critical problem throughout El Salvador. This pollution increases infant mortality rates and other indicators of poor public health and has a negative impact on rivers, lakes, and ground water. Much of the surface water is contaminated and not developed for water supply, so ground water from deeper wells and springs is, therefore, relied upon for domestic, industrial, agricultural, and municipal water supplies. Though ground water quality is generally good, biological and chemical contamination is common in shallow alluvial aquifers near populated places.

Poor water quality, brackish or saline water, also occurs naturally near geothermal and coastal areas. Saltwater intrusion contaminates wells in coastal regions and within the river deltas along the coast.

Specific data on water quality are not available, but several officials interviewed for this assessment informed the team that overall, surface waters have experienced significant increases in levels of contaminants over the past two decades.

1. Surface Water Quality

Although surface water is plentiful, biological contamination occurs nationwide, especially near heavily populated areas. Except for some primary treatment facilities, mostly near urban areas, all domestic and industrial effluent is released into the rivers and coastal areas without any treatment. According to officials with ANDA, a French-financed project will build two sewage treatment plants for San Salvador, with construction expected to take 2 to 3 years. New regulations have been adopted that will force new industries to remove at least 90 percent of the solids from their effluent prior to discharging into the streams. This regulation does not apply to the numerous existing sources of industrial contamination.

The major source of surface water contamination is from untreated domestic and industrial waste disposal. A 1991 water quality study of southwest El Salvador indicates extreme contamination from fecal matter. The study shows that 45 percent of the sampled water contains more than 9,000 fecal coliform bacteria counts per 100 milliliters of water. Many of these samples show more than 24,000 fecal coliform bacteria counts per 100 milliliters of water. Potable water should not contain any fecal coliform concentrations (i.e., zero fecal coliform bacteria counts per 100 milliliters of water). Industrial organic waste contamination in the water is primarily from the agricultural industry. Coffee-processing plants, sugar-processing plants, hemp-processing plants, distilleries, tanneries, milk plants, textile factories, and slaughterhouses are the main sources of industrial water pollution. All surface water sources should be treated before use.

Chemical contamination from pesticide use is also widespread, particularly in cotton-growing areas in the southeast coastal plain. Dichlorodiphenyl trichloroethane (DDT) is a common pesticide in El Salvador. In the Rio Grande de San Miguel, concentrations of 3.15 milligrams of DDT per liter of water have been found, which is over three times the lethal limit for fish. Rivers and streams in the major agricultural areas are reported to be highly contaminated with agricultural chemicals and pesticides.

Severely contaminated water dominates the main stem of the Rio Acelhuate, which serves as the drainage of San Salvador. High levels of organic chemicals render the water untreatable by reverse osmosis. Very high levels of contaminants combine to render the river a biohazard, and all contact with the river water should be avoided.

Natural degradation occurs near active volcanoes. In hydrothermal areas, the influx of thermal ground water degrades existing lakes and streams. Lago de Ilopango is a volcanic lake that stores brackish water with high levels of boron, chloride, sodium, and potassium. The lake drains through the Rio El Desague into the Rio Jiboa, adversely affecting the river's water quality. The Rio Jiboa water is slightly brackish, becoming less brackish toward the coast. Lago de Coatepeque is a volcanic lake without a surface water outlet, which stores an enormous quantity of brackish water. The lake water temperature is above normal. Water in the Rio Agua Caliente in the Rio Paz basin is also brackish because of hydrothermal activity.

Saline or brackish water exists in lagoons and estuaries along the Pacific coast. The lagoons contain both brackish and saline waters while the estuaries contain saline water. Brackish water in coastal mangrove swamps may contain large amounts of organic materials, iron, and magnesium.

2. Ground Water Quality

Though ground water quality is generally good, notable exceptions exist for areas of saline or brackish water near the coast, adjacent to mangroves, or near geothermal areas. Geothermal activity is probably common in deeper subsurface waters below the upper flanks of volcanoes, near fumaroles and thermal springs, or near streams such as the Rio Jiboa, that are fed by these waters. Temperatures of some spring waters are relatively hot (30 to 40 degrees Celsius (ºC)) and may be brackish and unpalatable to the taste, with nearby wells probably similarly affected. Geothermal ground water is more likely to contain excess concentrations of minerals which make it unfit for human consumption.

Biological contamination of shallow aquifers by pathogens due to improper disposal of human and animal wastes is a common problem. This is partly due to slow improvements in the design of sanitary disposal sites. Small domestic wells are also often located too close to latrines. Widespread public awareness programs can improve this situation. Shallow aquifer contamination affects areas surrounding even the smallest villages (caserios). Because the surface of the water table generally follows land contours, the contamination problem typically affects areas downslope of populated areas. Aquifers consisting of fractured or brecciated lava flows are particularly susceptible to contamination because water is transmitted rapidly in the subsurface with little or no filtering out of contaminants. Fracture systems may also transport the contamination in directions other than directly downslope. In areas of unconsolidated sediments, water produced from depths of less than 10 to 20 meters should be expected to be contaminated. Shallow perched aquifers in relatively unweathered volcanics are also frequently contaminated. Water obtained from wells next to streams is also likely to be contaminated with severe contamination existing in the aquifers adjacent to the Rio Acelhuate. This river contains high levels of organic compounds from industrial and domestic wastes and is the major recharge source for the aquifers along the river. Many of these contaminants cannot be reliably removed by reverse osmosis.

V. Recommendations

Almost all government agencies, companies, and private individuals that were interviewed during the country visit expressed interest in technical assistance and support. They are keenly aware of the country's need to apply more resources to planning, development, and management of their water resources.

Since the major source of surface water contamination is from untreated domestic and industrial waste disposal, a large construction program for new wastewater treatment plants is recommended along with enforced laws on proper effluent treatment. A large-scale ground water exploration program, beginning particularly in the areas of the best aquifers, would be beneficial, as most of the potable water supply for the country is from deeper wells and springs. The following recommendations reflect a composite of the needs identified by the assessment team and El Salvadoran officials.

A. Basic Technical Training

In our discussions with engineers, we were asked about training in water resources planning and engineering. The Corps has several state-of-the-art software training programs on the management of water resources. The Hydrologic Engineering Center (HEC) at Davis, California, has developed several of these software programs. Foremost is the HEC-2 program that is used to calculate water surface profiles. Other HEC software programs include data storage/management, planning, reservoir regulation, river hydraulics, statistical hydrology, and surface water hydrology. The Mobile District of the Corps has provided training of this nature to other Central American countries, and many of the users manuals are available in Spanish.

B. Watershed Management

Deforestation and water resources are major concerns in El Salvador; therefore development of comprehensive watershed or basin management plans are needed to address these issues. The intent of a watershed management plan is to achieve a comprehensive view of water and land resources problems within a watershed and identify opportunities and authorities to address such problems. Watershed planning is a systematic approach to evaluating alternate uses of the water and land resources to identify conflicts and trade-offs among competing uses so informed decisions can be made when changes are contemplated. Such plans should include short-term measures (i.e., erosion stabilization, bridge protection, flood warning systems, small water supply systems), interim measures (flood control actions, sediment control programs, flood plain management, small reservoirs) and long-term measures (reforestation, large impoundment for flood control, hydropower, and water supply). Hydrologic information on the major rivers in El Salvador is lacking. There is a critical need for additional river gages and the repair of broken ones. Sufficient hydrologic records are crucial to the development of watershed management plans and proper management of the water resources.

C. National Water Resources Management and Policy Recommendations

El Salvador's water resources development and management programs are decentralized. Data related to wells and surface water systems are maintained separately by the various agencies responsible for water resources. As a result, lack of coordination exists among agencies and to some extent among departments. This creates duplication of effort and a lack of exchange of technical knowledge and data.

The benefits of improving the water resources management and policy in El Salvador are enormous. The broad goals of such an effort would focus on public health, economic development, social well-being, and environmentally sustainable development. With an established framework, certain national policy issues and management strategies would emerge. This would require an assessment of the purposes of various water resources' projects such as water supply, water quality, irrigation, navigation, hydropower, fish and wildlife, etc. The in-country evaluation of all needs could lead to a restructuring of El Salvadoran water resources management and a more defined national interest and policy.

Water resources management and policy are the core of efficient and equitable development. Recommended approaches for gradual improvement of the current management system are as follows: (1) the formation of a water resources council; (2) the formation of a comprehensive water resources evaluation; (3) the establishment of a national clearinghouse; (4) the sponsoring of national and international meetings; and (5) the formation of task forces. These approaches are explained in the following paragraphs.

1. Water Resources Council

Formation of a water resources council at the national or international level would encourage information exchange and possibly shared organizational funding for common needs. The council should be made up of high-level executives from member entities. At the national level, candidate members would be heads of national offices and development corporation presidents. At the international level, candidate members would include the heads of the U. S. Agency for International Development (USAID), Cooperative for American Relief to Everywhere (CARE), European Economic Community, etc. Each of the members could assign staff to help on special studies and evaluations. The focus of any such council would be to discuss water resources activities in El Salvador and act as a policy advisor to El Salvador's President. It is conceivable that member nations or other entities could contribute to a fund which would finance common water resources development or interrelated needs. Examples of common needs are: development of a national data base for hydrology and hydraulics information, conservation of soil and water resources, and environmental enhancement. We encourage the permanent establishment of a 'Water Resources Council' to oversee El Salvador's water resources policy.

2. Comprehensive Water Resources Evaluations

The potential savings that could result from conducting comprehensive evaluations of all water resources and interrelated activities in El Salvador are enormous. Such an effort would require staffing for several years or a significant outside contract. The objective of the evaluations would be to analyze all ongoing and proposed water resources activities in El Salvador. This would require discussions with the literally hundreds of entities involved. These discussions would be followed with extensive field evaluations. After all the necessary field information has been collected, the long and arduous task of research and analysis can begin. This effort would uncover many commonalities and duplications which could be eliminated, allowing for a more cost-effective operation. There is also significant potential for savings due to economies of scale, such as consolidating numerous similar or identical efforts into one.

3. National Clearinghouse

Another method of assimilating information among various national and international entities would be through a clearinghouse. The first duty of this office would be to develop a mailing list of all entities which have an interest in a particular subject matter. Next, they would convince those involved in water resources development in El Salvador to forward their respective water resources proposals. Then they would simply mail pertinent data to appropriate parties upon request. There are two primary difficulties with this alternative. First, the expenses would be high due to the amount of staffing required. Second, there could be difficulty in obtaining uniform cooperation from all those involved. The only known examples of success with clearinghouses is in environments where the use of the process is mandated by force of law.

4. National and International Meetings

National and international symposia or meetings are a common means of encouraging the exchange of information. These can be an excellent forum for scientists, engineers, and water managers to exchange ideas, concepts and proven water resources management experiences. One word of caution - the meetings should not be too theoretical. There must be immediately implementable suggestions, as well as long-range proposals. We suggest that a national gathering, with selected international participation, would be a good initial meeting. This meeting would also be a good forum to discuss other national water policy alternatives, i.e., water resources council, comprehensive water resources evaluations, national clearinghouses, etc. The meeting should last from 3 to 7 days and be held in an easily accessible city such as San Salvador. Suggested topics and workshops to be covered include: national water policy issues, water conservation, drought management, major water resources projects either planned or under construction, experiments in changing crops, reforestation, soil erosion, irrigation techniques, well drilling, water quality, water treatment, and hydropower.

5. Formulation of Task Forces

This idea is somewhat similar to others previously discussed. The difference is that one major national agency would have to take the initiative to lead the program. The first step would be to identify a national need that would be of widespread interest to entities operating in El Salvador. Such needs might include a national water law, a national education program, a national data base for technical data, national surveys and mapping, and a national program for soil and water conservation. The lead agency would then need to correspond with the various national and international entities to co-sponsor the project by assigning members of their organization to the task force.

Another variation of the task force concept and the Water Resources Council idea involves the establishment of a Water Resources Commission. The task of this commission would be to evaluate the same national water policy issues discussed in the previous paragraph with a view toward making recommendations on water policy and the appropriate level of federal involvement. These recommendations should be documented in a report by the commission. The commission would consist of three to six high-level officials in El Salvador. The commission members would be appointed by the President for 1 to 3 years with staggering terms for consistency and fresh approaches. They should have a blend of various backgrounds - engineers, scientists, agricultural scientists, university professors, politicians, economists, and geologists are all good candidates. This commission would need a small staff to manage the details of the commission operation and to prepare and disseminate reports. The commission members would hold a series of public meetings and/or use a format of requesting testimony from a wide spectrum of professionals, agencies, and the general public. They would also solicit input from various national and international agencies. This, in effect, could result in a cost-free (to El Salvador) task force representing a variety of entities. From this pool of manpower, several committees and subcommittees could be formed to thoroughly evaluate various subjects related to national water policy, water agencies' involvement, and other national water resources needs.

6. Suggested Strategy

It is difficult to suggest a strategy because of our lack of knowledge of the reality of the bureaucracy and the political arena in El Salvador. A well-designed program in any of the areas discussed could conceivably be worthwhile. From an outsider's perspective, it appears a two-pronged approach would produce the greatest results. First, we would recommend the permanent establishment of a Water Resources Commission. This approach would involve the

El Salvadoran people and represent their views in lieu of the views of an "outside expert." The other suggested program is to conduct national and international symposia or meetings. The cost of the first effort will include an indirect need for staff to support the commission in the future.

D. Troop Exercise Opportunities

USSOUTHCOM currently provides assistance to El Salvador through its Humanitarian Civic Assistance exercises, which can include water well drilling. Water wells are sometimes drilled and used as water supply for troops during the exercise. Upon completion of the exercise, the successful wells are appropriately fitted and turned over to the communities for use as a water supply.

1. Small Surface Impoundments

Surface water supply should be considered for areas where development of ground water has been unsuccessful and for areas where ground water exploration may be too difficult for troop exercises. Examples of some of these areas are the department of Morazan and the northern mountainous areas. Extreme caution should be exercised in site selection because of the potential for contamination of the surface water. Design of these impoundments would not be difficult, and construction techniques would be very similar to those used in road or runway construction. The main design factors would be selecting a suitable site, sizing the embankment, and design of outlet structures. These impoundments should be considered only in areas where the surface water is not heavily polluted.

2. Well Exercises

There have been many U.S. military water well exercises in El Salvador since the early 1990's. Water wells are the primary source of potable water in El Salvador, so water well exercises will continue to be beneficial, as much of the surface water is not potable. The positive aspects of conducting well-drilling exercises in El Salvador include providing potable water in areas where contaminated surface water may be the sole water supply, and providing training for U.S. military troops and El Salvadoran drillers. As part of the U.S. troop engineering exercises, the installation of small hand pump wells, especially in the rural areas of El Salvador, could be of great benefit to El Salvador. These wells could be a source of safe potable water replacing contaminated surface water supplies in certain areas of the country.

Figure A-2 (with table A-2) should be used by planners as a general guide to selecting favorable areas for well drilling. Areas lying within map units 1 and 2 would be good areas to consider for potential well exploration. Caution should be exercised if selecting well exercise areas lying within map units 3 through 9. More detailed analysis for selected areas would be needed prior to site selection to obtain detailed site-specific hydrogeological data to estimate the potential for successful ground water exploration.

VI. Summary

Currently no laws exist, except for new industry, that regulate the discharge of domestic and industrial wastes. Many of the contamination problems are directly related to the lack of wastewater treatment plants and enforcement of treatment of effluent being discharged into the nation's waterways. As a result, most of El Salvador's abundant surface water is polluted and not normally developed for domestic water supplies. The overall health of El Salvador's population is also at risk as a result of this contamination.

Deforestation adds to the overall decline in the health of the rivers and reservoirs in El Salvador. Approximately 60 percent of the country's power is from hydropower generated from reservoirs on the Rio Lempa, which receive an estimated 7 million cubic meters per year of sedimentation from deforestation.

Access to water and sanitation services is very low in rural areas, contributing to poor living conditions and disease. In areas with inadequate access to safe water supplies, waterborne diseases are the greatest health hazard. Waterborne diseases such as dysentery are the major cause of infant mortality in the country.

Ground water is the major source of potable water. Sufficient supplies of fresh ground water are available throughout most of El Salvador. Springs and deeper wells provide ground water for drinking and industrial water supply because many shallow aquifers are becoming contaminated. Pollution of ground water sources, while not widespread, can locally be a serious problem. The two most significant pollution problems are biological contamination of ground water by human and animal wastes and chemical contamination by the infiltration of agricultural chemicals, particularly pesticides, into the aquifers. Industrial chemical contamination is generally concentrated in small areas.

Technical training, watershed management, development of a national water resources management plan, construction of more wastewater treatment plants coupled with enforced effluent-discharge treatment laws, construction of small surface impoundments, and well-drilling exercises are recommendations that present opportunities to improve El Salvador's water resources situation. If adopted, these actions can have positive long-term impacts. Many of the issues discussed in this report will require long-term commitments to affect a change.

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Glossary

alluvium	Sediment deposited by flowing water, as in a riverbed, flood plain, or delta.
andesite	A fine- to medium-grained, hard, dense, brown to gray, volcanic igneous rock. Andesite is generally of moderate use for engineering purposes.
aquifer	A body of rock that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.
artesian	Describes ground water which is under sufficient pressure that it can rise above the aquifer containing it. Flowing artesian wells are produced when the pressure is sufficient to force the water above the land surface.
basalt	A very fine-grained, hard, dense, dark-colored igneous rock which occurs widely in lava flows. Basalt is generally a high-quality source for all construction uses; however, it is very difficult to drill through.
basin	A low area toward which streams flow from adjacent hills. Ordinarily, a basin opens either toward the sea or toward a downstream outlet; but in an arid region without an outlet, a basin can be completely surrounded by higher land.
bicarbonate (HCO_3)	A negatively charged ion which is the dominant carbonate system species present in most waters having a pH value between 6.4 and 10.3. Excessive concentrations typically result in the formation of scale.
brackish water	Water that contains more than 1,000 milligrams per liter but not more than 15,000 milligrams per liter of total dissolved solids.
breccia	Gravel-size or larger angular rock fragments in a finer grained material. Breccia is usually a highly unpredictable rock for construction purposes, and it is normally avoided by the military engineer.
brecciated	Resembling a breccia in structure; e.g., rock that has been so thoroughly fractured that it appears to be composed of individual highly angular fragments.
caldera	A large, basin-like, ringed depression caused by the destruction or collapse of a volcanic cone. Commonly ringed by a circular ridge.
carbonate	A salt or mineral containing the radical CO_3.
carbonate rock	A rock, such as limestone or dolomite, that consists mainly of carbonate minerals.
caserio	Small village or group of dwellings in rural surroundings.
chloride	A negatively charged ion present in all natural waters. Excessive concentrations are undesirable for many uses of water. Chloride may be used as an indicator of domestic and industrial contamination.
confined aquifer	An aquifer bounded above and below by impermeable beds, or by beds of distinctly lower permeability.
consolidated	Where loosely aggregated, soft, or liquid earth materials have become firm and coherent rock.
corrosion	Removal of material from a surface by chemical means.

crater lake	A lake generally of fresh water, formed by the accumulation of rain and ground water in a volcanic crater or caldera with relatively impermeable floor and walls.
DDT	DDT (dichlorodiphenyl trichloroethane) is a colorless contact insecticide toxic to human beings and animals when swallowed or absorbed through the skin.
drawdown	The lowering of the water table or pressure head in a single well or entire aquifer due to the withdrawal of water.
encrustation	Formation of a crust or coating on a surface.
eruption	The ejection of volcanic materials onto the Earth's surface.
estuary	An arm of the sea that extends inland to meet the mouth of a river.
fecal coliform	A group of bacteria which is normally abundant in the intestinal tracts of man and other warm-blooded animals, used as indicators (measured as the number of individuals per milliliter of water) when testing the sanitary quality of water.
formation	Strata or series of strata of rock or sediment showing distinct and unifying lithologic properties or characteristics and large enough to be mapped. A formation is usually tabular in shape.
fracture	A crack, joint, fault, or other break in rock.
fresh water	Water that contains 600 milligrams per liter or less of chlorides, 300 milligrams per liter or less of sulfates, and 1,000 milligrams per liter or less of total dissolved solids.
gaging station	A location on a stream where water levels are measured to record discharge and other parameters.
geothermal area	Area where subsurface temperatures are elevated significantly above average.
Holocene	The most recent geologic time division, from 10,000 years ago to the present, starting at the end of the Pleistocene. Holocene is synonymous with Recent.
igneous	A class of rock formed by the solidification of molten material. If the material is erupted onto the Earth's surface, the rock is called an extrusive or volcanic rock; if the material solidifies within the Earth, the rock is called an intrusive or plutonic rock.
interbedded	Occurring between or lying in with other sediments or rock units; interstratified.
interflow	Layers of alluvium or other nonvolcanic material bounded above and below by lava flows.
intermittent (stream)	A stream or reach of a stream that flows only at certain times of the year, as when it receives water from springs or from some surface source, such as rain.
lagoon	A shallow body of water with a restricted inlet from the sea that contains both brackish and saline water.
lapilli	Deposit of loose to lightly compacted, typically scoriaceous volcanic fragments 2 to 64 millimeters in diameter.
lava	Fluid rock such as that which issues from a volcano or a fissure in the Earth's surface. Lava is also the same material solidified by cooling.
lithology	Typically denotes a type of rock, i.e. sedimentary, metamorphic, or igneous.

mangrove	A group of plants that grows in a tropical or subtropical marine swamp. A marine swamp dominated by a community of these plants.
organic (compounds)	Compounds of carbon (excluding carbonates, bicarbonates, carbon dioxide, and carbon monoxide) in domestic sewage such as metabolic wastes from feces, urine, grease, oil, and detergents. These compounds may be broken down by bacteria which consume the oxygen in a body of water during the process.
pathogen	Disease-causing microorganism, such as a virus or bacterium.
perennial stream	A stream that flows year-round and has a minimum flow of 40 liters per minute. A perennial stream is usually fed by ground water, and its water surface generally starts at a lower level than that of the water table in the area.
permeability (rock)	The property or capacity of a porous rock for transmitting a fluid. Permeability is a measure of the relative ease of fluid flow under unequal pressure. The customary unit of measure is a millidarcy.
pH	A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale commonly in use ranges from 0 to 14.
Pleistocene	Division of geologic time between 10,000 and 1.6 million years ago that falls chronologically after the Pliocene and before the Holocene.
Pliocene	Division of geologic time between 1.6 million and 5 million years ago that falls chronologically after the Miocene and before the Pleistocene. The Pliocene is the last time division of the Tertiary Period.
potable water	Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.
pumice	A vesicular, glassy, fine-grained, felsic (silica-rich) extrusive igneous rock. Pumice generally forms as a crust on the surface of felsitic lava flows or as pyroclastic blocks.
pyroclastic	Describes loose to highly compacted material composed of volcanic fragments that were erupted in semisolid to solid state.
Recent	The most recent geologic time division, from 10,000 years ago to the present. Starting at the end of the Pleistocene. Recent is synonymous with Holocene.
recharge	Addition of water to the zone of saturation from precipitation, infiltration from surface streams, and other sources.
reservoir	A pond, lake, tank, basin, or other space that is used for storage, regulation, and control of water for recreation, power, flood control, or drinking. A reservoir can be either natural or manmade.
reverse osmosis	A water purification treatment technology appropriate for meeting drinking water regulations that removes inorganic contaminants and dissolved solids. This method reduces contaminants by 90 to 95 percent by a membrane permeation process that separates relatively pure water from a less-pure solution.
saline water	Water containing greater than 15,000 milligrams per liter of total dissolved solids. Saline water is undrinkable without treatment.
saltwater intrusion	Displacement of fresh surface or ground water by the advance of salt water due to its greater density. Saltwater intrusion usually occurs in coastal and estuarine areas where it contaminates fresh water wells.

scoria	A vesicular, cindery, fine-grained, dark-colored, mafic (silica-poor) extrusive igneous rock with a stony or glassy texture. Scoria generally forms as a crust on the surface of basaltic lava flows. This volcanic rock, consisting of at least 50 percent void space, typically forms from the rapid solidification of lava rich in gas bubbles.
seismic	Pertaining to earthquakes or ground shaking.
sulfate	The negatively charged divalent ion SO_4^{2-} present in natural waters. Excessive concentrations are undesirable for many uses of water, due to mild to moderate corrosive properties. Sulfate may have laxative properties at levels exceeding 600 to 1,000 milligrams per liter.
Tertiary	The first major division of geologic time in the Cenozoic Era, 1.6 to 66 million years ago. The Tertiary is characterized worldwide by volcanic activity and the formation of mountains.
thermal spring	A hot or warm spring, in which the water produced has been heated by natural processes.
total dissolved solids (TDS)	The sum of all dissolved solids in water or waste water.
transmissivity (T)	The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient; the rate at which water passes through a unit width of an aquifer.
Tropical maritime (mT)	The principal type of air mass that is produced over the tropical and subtropical seas. It is very warm and humid, and it is frequently carried poleward on the western flanks of the subtropical highs.
turbidity	A measure of the reduction in water clarity. Unclear or muddy water is caused by suspended particles of sand, silt, clay, or organic matter. Excessive turbidity must be removed to make water potable.
unconfined aquifer	An aquifer where the water table is exposed to the atmosphere through openings in the overlaying material.
unconsolidated	Loose, soft, or liquid earth materials that are not firm or compacted.
volcanic ash	Fine pyroclastic matter composed of particles that are less than 2 millimeters in diameter.
water table	The depth or level below which the ground is saturated with water.
watershed	The area contained within a drainage divide above a specified point on a stream.

APPENDIX A

Water Resources Departmental Summary of El Salvador

List of Place Names

Place Name	Geographic Coordinates
Acajutla	1335N08950W
Aguilares	1357N08911W
Ahuachapan	1355N08951W
Bahia de Jiquilisco	1314N08833W
Bahia de La Union (bay)	1322N08749W
Cerro el Pital (mountain)	1423N08908W
Cerro Nejapa	1349N08913W
Cerro Monte Cristo	1425N08921W
Cerro Tecomatepe	1351N08903W
Chalatenango	1402N08856W
Coastal Plains and Lowlands (drainage region)	1320N08850W
Cojutepeque	1343N08856W
Colima	1403N08908W
Cordillera Alotepeque-Metapan	1420N08915W
Cordillera Cacahuatique-Coroban	1347N08807W
Cordillera de Jucuaran (mountains)	1314N08810W
Cordillera Jucuaran-Intipuca	1315N08810W
Cutuco	1320N08749W
Embalse Cerron Grande (reservoir)	1400N08910W
Embalse Presa Cinco de Noviembre (reservoir)	1358N08848W
Embalse del Guajoyo (reservoir)	1414N08928W
Embalse Quince de Septiembre (also Embalse del San Lorenzo) (reservoir)	1343N08830W
Estero de Jaltepeque (lagoon)	1319N08855W
Golfo de Fonseca (gulf)	1310N08740W
Interior Highlands and Valleys (drainage region)	1400N08900W
Isla Conchaguita	1314N08746W
Isla El Tigre (in Honduras)	1316N08738W
Isla Meanguera	1311N08743W
Isla Meanguerita	1310N08741W
Lago de Coatepeque (lake)	1352N08933W
Lago de Guija (lake)	1416N08031W
Lago de Ilopango (lake)	1340N08903W
Laguna Olomega (lake)	1319N08804W
La Hachadura	1351N09006W
Nueva San Salvador	1341N08917W
Paso de Le Ceiba	1425N08926W
Perequin	1357N08810W
Punta Conchaguita	1310N08808W
Punta de Amapala (cape)	1310N08754W
Punta Gorda	1319N08949W
Punta La Bolsa (approximate)	1322N08749W
Punta Remedios	1331N08949W
Punta San Juan	1311N08828W
Quezaltepeque	1350N08916W
Rio Acahuapa	1334N08839W
Rio Acelhuate	1404N08908W
Rio Agua Caliente	1348N08423W

List of Place Names, Continued

Place Name	Geographic Coordinates
Rio Agua Caliente	1403N08952W
Rio Banderas	1332N08943W
Rio Cara Sucia	1344N09002W
Rio Chingo	1402N08944W
Rio Comalapa	1325N08910W
Rio Copinula	1358N08920W
Rio Cusmapa	1413N08931W
Rio Desague	1415N08929W
Rio de Sonsonate	1343N08944W
Rio El Desague	1340N08859W
Rio El Guayabo	1316N08850W
Rio El Molino	1357N08957W
Rio El Molino	1316N08827W
Rio El Potrero	1320N08841W
Rio El Terrero	1323N08847W
Rio Goascoran	1325N08748W
Rio Grande de San Miguel	1314N08822W
Rio Guajoyo	1414N08928W
Rio Guayapa	1341N09000W
Rio Gueveapa	1403N08952W
Rio Jalponga	1322N08857W
Rio Jiboa	1322N08904W
Rio Lempa	1315N08849W
Rio Los Limones	1340N08825W
Rio Negro	1400N08810W
Rio Paz	1345N09008W
Rio Pululuya	1333N08942W
Rio Quezalapa	1357N08900W
Rio San Antonio	1352N08801W
Rio San Francisco	1348N09003W
Rio Santa Ana (also Rio de Canas)	1354N08819W
Rio Sapo	1349N08808W
Rio Sensunapan (also Rio Grande de Sonsonate)	1336N08951W
Rio Sirama (also Rio Amatillo)	1327N08748W
Rio Sucio	1402N08917W
Rio Sumpul	1402N08848W
Rio Titihuapa	1345N08832W
Rio Torola	1352N08830W
Rio Unire	1349N08743W
San Cristobal	1411N08940W
San Ignacio	1420N08911W
San Ildefonso	1342N08834W
San Luis	1342N08905W
Santa Clara	1335N08747W
Santa Cruz	1401N08953W
Santiago Nonualco	1331N08857W
San Vicente (valley)	1339N08848W

List of Place Names, Continued

Place Name	Geographic Coordinates
Sierra Apaneca-Ilamatepec	1355N08943W
Sierra La Libertad-San Salvador-San Vicente	1340N08905W
Sierra Nahuaterique	1350N08800W
Sierra Tecapa-Chinameca	1330N08825W
Volcan de Conchagua (mountain)	1316N08750W
Volcan de San Salvador	1344N08917W
Volcan de San Vicente	1336N08851W
Volcan de Usulutan	1325N08828W

Note:
Geographic coordinates for place names and primary features are in degrees and minutes of latitude and longitude. Latitude extends from 0 degrees at the Equator to 90 degrees north or south at the poles. Longitude extends from 0 degrees at the meridian established at Greenwich, England, to 180 degrees east or west established in the Pacific Ocean near the International Date Line. Geographic coordinates list latitude first for the Northern (N) or Southern (S) Hemisphere and longitude second for the Eastern (E) and Western (W) Hemisphere. For example:

Acajutla....................................1335N08950W

Geographic coordinates for Acajutla that are given as 1335N08950W equal 13°35' N, 89°50' W and can be written as a latitude of 13 degrees and 35 minutes north and as a longitude of 89 degrees and 50 minutes west. Coordinates are approximate. Geographic coordinates are sufficiently accurate for locating features on the country scale map. Geographic coordinates for rivers are generally at the river mouth.

A. Introduction

This appendix summarizes the water resources information of El Salvador, which can be useful to water planners as an overview of the available water resources. Figure A-1, Surface Water Resources, divides the country into surface water categories, identified as map units 1 through 7. Table A-1, which complements figure A-1, details the quality, quantity, and seasonality of significant water features within each map unit of El Salvador, and describes accessibility to these water sources. Figure A-2, Ground Water Resources, divides the country into categories with similar ground water characteristics identified as map units 1 through 9. Table A-2, which complements figure A-2, details the predominant ground water characteristics for each map unit of El Salvador, such as aquifer materials and thickness, depth to water, yields, and water quality. A summary of the water resources of each department is provided, based mainly on these figures and tables.

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B. Water Conditions by Map Unit

Figure A-1 divides El Salvador into seven map unit categories based on water quality and quantity. Map units 1 through 3 depict areas where fresh surface water is perennially available in moderate to enormous quantities. Map unit 4 depicts areas where fresh surface water is seasonally available in moderate to enormous quantities from early May through October. Map units 5 and 6 depict areas where fresh surface water is scarce or lacking. Map unit 5 also depicts areas where small to large quantities may be available from intermittent streams from early May through October, but the stream channels are dry during the rest of the year. Map unit 6 also depicts areas where very large to enormous quantities of brackish or saline water are available from streams, lakes, coastal, lagoons, and mangrove swamps year-round. Map unit 7 depicts the highly contaminated water of the Rio Acelhuate. Figure A-1 also divides the country into 11 major river basins labeled I through XI. Several river basin boundaries cross both department and international borders.

Figure A-2 divides El Salvador into nine map unit categories based on water quality and quantity. Map units 1 and 2 depict areas where ground water development appears to be the most favorable and fresh water is generally plentiful. Map units 3 and 4 depict areas where fresh water is locally plentiful. Map units 5 through 9 depict areas where fresh water is scarce or lacking or areas where the ground water is brackish to saline.

Surface water and ground water quantity and quality are described for each department by the following terms:

Quantitative Terms:

Enormous	= >400,000 liters per minute (100,000 gallons per minute)
Very large	= >40,000 to 400,000 liters per minute (10,000 to 100,000 gallons per minute)
Large	= >4,000 to 40,000 liters per minute (1,000 to 10,000 gallons per minute)
Moderate	= >400 to 4,000 liters per minute (100 to 1,000 gallons per minute)
Small	= >40 to 400 liters per minute (10 to 100 gallons per minute)
Very small	= >4 to 40 liters per minute (1 to 10 gallons per minute)
Meager	= $\leq$4 liters per minute (1 gallon per minute)

Qualitative Terms:

Fresh water = maximum total dissolved solids (TDS)* ≤1,000 milligrams per liter; maximum chlorides ≤600 milligrams per liter; and maximum sulfates ≤300 milligrams per liter

Brackish water = maximum TDS >1,000 milligrams per liter but ≤15,000 milligrams per liter

Saline water = *TDS >15,000 milligrams per liter

*TDS is the concentration of minerals in water. Most of the dissolved minerals are inorganic salts also described as *salinity*. The World Health Organization guideline for the maximum recommended level of drinking water quality for TDS is 1,000 milligrams per liter.

C. Water Conditions by Department

The following data was compiled for each department from information contained in figures A-1 and A-2 and tables A-1 and A-2. The write-up for each department consists of a general and regional overview of the surface water and ground water resources derived from a country scale overview. Locally, the conditions described may differ. Site-specific reconnaissance may reveal different water conditions than those indicated by the map unit categories. The department summaries should be used in conjunction with figures A-1 and A-2. Tables A-1 and A-2 contain more detailed technical information. Additional information is necessary to adequately describe the water resources of a particular department or region. Specific well data were limited and for many areas unavailable. For all areas that appear to be suitable for tactical and hand pump wells, local conditions should be investigated before beginning a well-drilling program.

Ahuachapan Department

Area and relative size: 1,240 km^2
Eighth out of 14 departments (6 percent of country)

1997 Population (est.): 300,938
5 percent of total population

Ahuachapan is the westernmost department in El Salvador with Guatemala on the western border and the Pacific Ocean to the south.

Surface Water

Rio Paz, a major river on the Guatemalan border, forms the western border of the department. The Rio Gueveapa (also known as Rio Pampe) is the other major river in the department. These rivers lie within map unit 1 and have enormous quantities of fresh water available year-round, except from November to April when Rio Gueveapa yields slightly less. The lower reaches of smaller streams in the department, such as Rio El Molino, Rio Cara Sucia, and Rio Guayapa, yield at least large to moderate quantities of fresh water year-round. Most of the department lies in map units 4 and 5, where fresh water is only seasonally available from early May through October. The capital city of Ahuachapan lies within map unit 4, near Rio El Molino. The Rio Agua Caliente and the Pacific coastal area lie within map unit 6 where brackish to saline water is available year-round.

Ground Water

The most favorable areas for ground water exploration are depicted by map unit 1, which is in the northernmost area and covers about 30 percent of the department. The capital city of Ahuachapan lies within this area. Other favorable areas for ground water exploration are in the southern part of the department, depicted by a small area of map unit 2 and map unit 3.

Ground water exploration during military exercises is not recommended in the rest of the department depicted by map units 4, 5, and 8. Specialized civilian technical expertise in water well drilling may have marginal success in these areas. Map unit 5 areas lie in the Sierra Apaneca-Ilamatepec in the central-eastern part of the department, and comprises about 10 to 15 percent of the department. This area is characterized by rugged terrain, with the regional ground water table at great depth. Brackish to saline water, depicted by map unit 8, is available from the coastal plain aquifers along the Pacific coast.

Cabanas Department

Area and relative size: 1,104 km^2
Twelfth out of 14 departments (5 percent of country)

1997 Population (est.): 150,173
<3 percent of total population (the least-populated department)

The northern boundary of this department is shared with Honduras along the Rio Lempa.

Surface Water

Most of the surface water that is available year-round is from the rivers and the reservoirs that form most of the departmental boundary, as depicted by map unit 1. Rio Lempa, Rio Titihuapa, Rio Quezalapa, Embalse Presa Cinco de Noviembre, and Embalse Quince de Septiembre along the boundaries, contain most of the department's fresh surface water available year-round in very large to enormous quantities. The Embalse Presa Cinco de Noviembre and the Embalse Quince de Septiembre are major reservoirs on the Rio Lempa which provide hydropower to El Salvador. Part of the Embalse Presa Cinco de Noviembre lies within the department and has a capacity of 81 kilowatts. Part of the Embalse Quince de Septiembre also lies within the department, having a capacity of 180 kilowatts. Both of these reservoirs have enormous quantities of fresh water available year-round. The rest of the department (about 80 to 90 percent) has fresh water only seasonally available from early May through October.

Ground Water

Ground water exploration during military exercises is not recommended in about 90 percent of the department depicted by map unit 4. These areas consist of older volcanics, where successful ground water exploration may be dependent upon encountering water-bearing fractures during drilling. The capital city of Sensuntepeque lies within map unit 4. The rest of the department lies within map unit 3 in volcanics mainly of the Cuscatlan Formation. Specialized civilian technical expertise in water well drilling may have marginal success in these areas, with the most successful wells located on fracture zones.

Chalatenango Department

Area and relative size: 2,017 km^2
Fifth out of 14 departments (9.5 percent of country)

1997 Population (est.): 192,601
3 percent of total population

The northern boundary of this department is the border with Honduras.

Surface Water

Most of the department lies in map unit 4, where moderate to enormous quantities of fresh water are seasonally available only from early May through October from small lakes and intermittent streams. About 20 percent of the department, in the north and east, is in map unit 5 where small to large quantities of fresh water are seasonally available only from ephemeral or intermittent streams from early May through October. A large part of the Embalse Cerron Grande, the largest reservoir in El Salvador, lies along the Rio Lempa and is in the southern part of the department. This reservoir is used for hydropower and has a capacity of 135 kilowatts. The Embalse Presa Cinco de Noviembre, another major reservoir used for hydropower, also lies along the Rio Lempa in the southeastern part of the department, having a capacity of 81 kilowatts. These reservoirs yield very large to enormous quantities of fresh water year-round. The Rio Lempa and the reservoirs form most of the eastern, western, and southern departmental boundaries. The Rio Sumpul, a major river that lies within map unit 1 and yields very large to enormous quantities of water year-round, forms a large part of the department's northern boundary, shared with Honduras. Chalatenango, the department capital, lies north of the Rio Tamulasco, a medium-sized stream in map unit 2, which yields large to very large quantities of fresh water year-round.

Ground Water

About 15 percent of the department lies within areas that would generally be favorable for ground water exploration during military exercises, as depicted by map units 1 and 3. These areas are in the southern and southwestern parts of the department. The rest of the department lies within map units 4 and 6, where groundwater exploration is not recommended during well exercises. Specialized civilian technical expertise in water well drilling may have marginal success in these areas. The capital city of Chalatenango lies in map unit 4.

Cuscatlan Department

Area and relative size: 756 km^2
The smallest department in El Salvador (3.5 percent of country)

1997 Population (est.): 196,413
3 percent of total population

This department is in central El Salvador.

Surface Water

Most of the department, including the capital city of Cojutepeque, has fresh surface water only seasonally available from early May through October, as depicted by map unit 4. About 10 percent of the department, map units 1 and 2, has fresh water available year-round, including Embalse Cerron Grande, Rio Quezalapa, and a small area in the southernmost part of the department on the boundary. A small part of the department along the northwestern boundary contains highly contaminated water from Rio Acelhuate. Lago de Ilopango, which is of volcanic origin, lies partially within the department in the southwest corner and stores brackish water year-round.

Ground Water

Ground water exploration during military exercises could be considered in about 70 percent of the department in areas of map units 1 and 3. The capital city of Cojutepeque is located in map unit 3 in the southern part of the department. Map unit 3 consists of volcanics, mainly of the Cuscatlan Formation where ground water exploration would be moderately successful with best yields located on fracture zones. Two small isolated areas of map unit 1, which are the most favorable areas for ground water exploration, are located east of Rio Acelhuate and north of Lago de Ilopango.

The rest of the department consists of the highly contaminated aquifers associated with Rio Acelhuate, brackish water near Lago de Ilopango and map unit 5 areas of steep volcanic slopes. These areas are not recommended for ground water exploration.

La Libertad Department

Area and relative size: 1,653 km^2
Sixth out of 14 departments (8 percent of country)

1997 Population (est.): 622,509
11 percent of total population (second most-populated department)

The Pacific Ocean forms the southern boundary of the department. The department has abundant water resources. Part of Volcan de San Salvador lies in the central part of the department.

Surface Water

La Libertad has a few major rivers that lie within map unit 1 in the northern part of the department, such as Rio Lempa, Rio Sucio and part of Rio Suquiaca. These major rivers have very large to enormous quantities of fresh water available year-round. There are several medium-sized streams, such as Rio Chilama and part of Rio El Sunzal, that have large to very large quantities of fresh water available year-round in their lower reaches. Less than 15 percent of the department falls within map units 1, 2, and 3, where fresh water is available year-round. Most of the department lies within map unit 4, including the capital city of Nueva San Salvador, where moderate to enormous quantities of fresh water are seasonally available only from early May through October. About 15 percent of the department lies within map unit 5, located near Volcan de San Salvador, and in a mountain range running east-west across the south central part of the department. In these areas, small to large quantities of fresh water are only seasonally available from early May through October.

Ground Water

Ground water exploration during military exercises is recommended in map units 1 and 3, which cover almost half of the department in the central and eastern parts. Map unit 1 lies in the central part of the department (except in the steep upper slopes of the Volcan de San Salvador), including the capital city of Nueva San Salvador, where ground water exploration would be most favorable, mainly in the volcanic San Salvador Formation. Most of map unit 3 lies along the northeastern boundary of the department, where most of the aquifers consist of volcanics of the Cuscatlan Formation. Wells sited along large fractures in these map unit 3 areas may yield sufficient quantities for municipal and irrigation wells.

The rest of the department lies within map units 4, 5, and 8, in which ground water exploration is not recommended during military exercises due to either older volcanics or poor quality water expected to be encountered. Specialized civilian technical expertise in water well drilling may have marginal success in these areas, but the areas of map unit 8 should be avoided due to poor quality water. Map unit 4 occupies about half of the department, where successful ground water exploration may depend upon encountering water-bearing fractures in the older volcanics. Map unit 5 lies along the steep upper slopes of Volcan de San Salvador where the regional ground water table is very deep. A small area north of Volcan de San Salvador lies in map unit 8 where brackish to saline ground water is anticipated. Map unit 8 also lies along the coastal areas, where brackish or saline water is anticipated to be encountered in alluvial wells. Ground water exploration is not recommended in map unit 8, particularly where the ground elevation is less than 10 meters above mean sea level, due to the potential for poor quality water.

La Paz Department

Area and relative size: 1,224 km^2
Tenth out of 14 departments (6 percent of country)

1997 Population (est.): 278,465
5 percent of total population

The Pacific Ocean forms the southern boundary of the department. The department has abundant water resources. Part of Volcan de San Vicente lies in the northeastern part of the department.

Surface Water

Many medium-sized streams in La Paz that discharge into the Pacific Ocean have large to very large quantities of fresh water available year-round in their middle to lower reaches, such as Rio Comalapa and Rio Jalponga. About 10 percent of the department lies within these areas of map unit 2. Most of the department, including the capital city of Zacatecoluca, lies within map unit 4, where moderate to enormous quantities of fresh water are seasonally available from small intermittent streams from early May through October. Map unit 6 areas are near Lago de Ilopango in the northern part of the department, and along the Rio Jiboa and parts of the coast, where brackish to saline water is available year-round. Lago de Ilopango is of volcanic origin and has high mineral content that adversely affects water quality, and therefore degrades the surface water bodies it feeds, such as Rio Jiboa.

Ground Water

La Paz is rich in ground water resources, particularly in the coastal plain, where alluvial aquifers are found. Numerous successful large-capacity water wells have been installed here. All alluvial aquifers in this area (map unit 2) are suitable for hand pump wells, and most are suitable for tactical wells. Alluvial aquifers along the Rio Comalapa, Rio Sepaquiapa, Rio Jalpongo, and the Rio Sapuyo are suitable for municipal or irrigation wells. Part of Volcan de San Vicente lies in the northeastern part of the department. South and west of the volcano, to the coastal plain, lie map unit 3 areas, where fresh water is locally plentiful from volcanic rock, consisting mainly of the Cuscatlan Formation. The capital city of Zacatecoluca is in this area. Ground water exploration during military exercises is recommended in the coastal plain, except where the ground elevation is less than 10 meters above mean sea level, and in map unit 3 described above, which collectively cover about half of the department.

The coastal areas immediately adjacent to the Pacific Ocean lie within map unit 8 where meager to large quantities of brackish to saline water are available from unconsolidated alluvium. Small areas surrounding Lago de Ilopango and along the Rio Jiboa also fall within this map unit. The rest of the department, which lies south of Lago de Ilopango, west of Rio Jiboa, and north of the coastal plain, is in map unit 4. Ground water exploration during military exercises is not recommended in these map units. Specialized civilian technical expertise in water well drilling may have marginal success in the areas of map unit 4, but well drilling should be avoided in the areas of map unit 8 due to the potential for poor quality water.

La Union Department

Area and relative size: 2,074 km^2
Third out of 14 departments (10 percent of country)

1997 Population (est.): 280,298
5 percent of total population

La Union is the easternmost department in El Salvador, with Honduras on the northern border, Honduras and the Bay of La Union on the eastern border, and the Pacific Ocean to the south.

Surface Water

Most of the department lies within map unit 4 where fresh surface water is seasonally available only during early May through October from small lakes and small intermittent streams in moderate to enormous quantities where sources are predominantly dry during the rest of the year. The capital city of La Union lies in this area. Rio Goascoran forms the eastern boundary of the country and department and is shared with Honduras. Fresh water is available from this river from the middle to lower reaches year-round in very large to enormous quantities. Water near the Bahia de La Union may be brackish or saline.

Ground Water

A few scattered areas, depicted by map units 2 and 3, cover about 20 percent of the department, mainly in the south and east, and are the most favorable areas for ground water exploration during military exercises.

Ground water exploration during military exercises is not recommended for most of this department. Specialized civilian technical expertise in water well drilling may have marginal success. Map unit 4, consisting of older volcanics, covers most of the department, and successful well exploration may depend upon encountering water-bearing fractures during drilling. Extensive field mapping, geophysical exploration, and/or test drilling would be helpful in locating more favorable well locations in these areas. Map unit 8 lies along the coast where brackish or saline water is anticipated to be encountered in alluvial wells. The capital city of La Union lies within map unit 8. Ground water exploration is not recommended in the areas of map unit 8 due to the potential for poor quality water, particularly where the ground elevation is less than 10 meters above mean sea level.

Morazon Department

Area and relative size: 1,447 km^2
Seventh out of 14 departments (7 percent of country)

1997 Population (est.): 170,861
<3 percent of total population (one of the least-populated departments)

The department of Morazon has one of the greatest needs for potable water in the country. The northern border is shared with Honduras in the eastern part of El Salvador.

Surface Water

Most of the department, including the capital city of San Francisco, lies within map unit 4 where fresh surface water is seasonally available only during early May through October from small lakes and small intermittent streams in moderate to enormous quantities, where sources are predominantly dry during the rest of the year. In about 15 percent of the department, along the Rio Torola, and the middle to lower reaches of the Rio Sapo, and Rio San Francisco, fresh surface water is available year-round in large to enormous quantities.

Ground Water

Ground water exploration during military exercises is not recommended in this department. Specialized civilian technical expertise in water well drilling may have marginal success. Older volcanics cover most of the department, and successful well exploration may depend upon encountering water-bearing fractures during drilling. Extensive field mapping, geophysical exploration, and/or test drilling would be helpful in locating more favorable well locations.

San Miguel Department

Area and relative size: 2,077 km^2
Second out of 14 departments (10 percent of country)

1997 Population (est.): 455,270
8 percent of total population (fourth most-populated department)

The department of San Miguel is in the eastern part of El Salvador and has abundant surface and ground water resources. The northern border is shared with Honduras.

Surface Water

Over half of San Miguel, including the capital city of San Miguel, lies within map unit 4, where moderate to enormous quantities of fresh water are available from small lakes and small intermittent streams from early May through October but are predominately dry the rest of the year. Rio Grande de San Miguel, Rio Lempa, and Rio Torola are major rivers that have very large to enormous quantities of fresh water available year-round. Downstream (south) of the capital city of San Miguel, the Rio Grande de San Miguel is more likely to be highly contaminated. Small surface impoundments should not be considered downstream of the city of San Miguel due to this potential for water contamination. Embalse Quince de Septiembre is a major reservoir on the Rio Lempa which provides hydropower to El Salvador. Part of this reservoir, which has a capacity of 180 kilowatts, lies within the department and has enormous quantities of fresh water available year-round. There are many smaller streams and lakes in the department that have large to enormous quantities of fresh water available year-round.

Ground Water

About 20 percent of the department including the city of San Miguel and areas west, north, and south of the city, lies in map unit 1, where moderate to very large quantities of fresh water are available mainly from the San Salvador Formation. The best areas for ground water exploration may be in the upper layers of this formation, except for the steep upper slopes of the volcano west of the city. Areas adjacent to Rio Grande de San Miguel, south of San Miguel city, are also favorable, however, the aquifers closest to the river may be contaminated from large amounts of waste from the city. The southern half of the department, north and west of Laguna Olomega is overall the most favorable area for ground water exploration, and consists predominantly of map units 1, 2, and 3. Areas to avoid within this region are the steep upper slopes of the volcano, areas adjacent to Laguna de San Juan, and the river that flows from it. Ground water exploration is recommended is the rest of the area.

The northern half of the department predominately lies within map unit 4 where small to moderate quantities of water are available from older volcanic rocks. These volcanics are less favorable for ground water exploration than the younger volcanics. Well locations should be sited in valley bottoms and/or along fracture sets. Successful wells may depend upon encountering water-bearing fractures in the borehole. Ground water exploration during military exercises is not recommended in this area. Specialized civilian technical expertise in water well drilling may have marginal success here.

San Salvador Department

Area and relative size: 886 km^2
Thirteenth out of 14 departments (4 percent of country)

1997 Population (est.): 1,831,532
31 percent of total population (the most-populated department)

The nation's capital, San Salvador, lies within this department, which is also the departmental capital. Severely contaminated water in Rio Acelhuate, which is the drainage for San Salvador, dominates the department. The city of San Salvador withdraws about 1.5 m^3/sec from the Rio Lempa, with the rest of its water coming from wells within a 15-kilometer radius of the city.

Surface Water

The drainage for San Salvador is the Rio Acelhuate, which originates west of San Salvador, flows through the city then flows north to Rio Lempa. Improper disposal of wastes from San Salvador into the Rio Acelhuate has caused severe contamination of the water, rendering the river a biohazard. Map unit 9 is designated for the Rio Acelhuate.

About 10 percent of the department lies within map units 1 and 2, where large to enormous quantities of fresh water are available year-round from streams, lakes and reservoirs. The Rio Lempa, which forms the northern departmental boundary, and the Rio Sucio in the northwestern part of the department, are the major rivers. The westernmost part of the Embalse Cerron Grande, El Salvador's largest reservoir, lies in the northeastern part of the department. Rio Acelhuate, however, flows into the Rio Lempa and the Embalse Cerron Grande, dumping huge amounts of contamination.

About 70 percent of the department lies within map unit 4, where fresh water is seasonally available only from early May through October from small intermittent streams. Lago de Ilopango, most of which lies within the department, stores about 27 million cubic meters of water, is of volcanic origin and has high mineral content that adversely affects water quality.

Ground Water

Ground water exploration is recommended in map units 1 and 3, which cover almost half of the department in the central and northern parts. Except for Rio Acelhuate and the adjacent areas, map unit 1 lies in the central part of the department, where ground water exploration would be most favorable, mainly in the volcanic San Salvador Formation. Map unit 3 lies predominatly in the northern part of the department, where aquifers consisting mainly of volcanics of the Cuscatlan Formation are found. Wells sited along large fractures in these areas may yield sufficient quantities for municipal and irrigation wells.

The rest of the department lies within map units 4, 5, 8, and 9, where ground water exploration during military exercises is not recommended due to either older volcanics or poor quality water expected to be encountered. Specialized civilian technical expertise in water well drilling may have marginal success in these areas, but the areas of map units 8 and 9 should be avoided due to the potential for poor quality water. Map unit 4 occupies the southern part of the department, south of San Salvador, and small isolated areas in the north, where older volcanics are expected. Successful ground water exploration in this map unit may depend upon encountering water-bearing fractures during drilling. Less than 10 percent of the department lies in map unit 5 along the steep upper slopes of Volcan de San Salvador and Cerro Nejapa, where the regional ground water table is very deep. Lago de Ilopango, of volcanic origin, is surrounded by map unit 8 areas, where brackish to saline ground water is anticipated. San Salvador, the nation's and the department's capital city, lies within map unit 9 where ground water exploration is not recommended due to severely contaminated water.

Santa Ana Department

Area and relative size: 2,023 km^2
Fourth out of 14 departments (9.5 percent of country)

1997 Population (est.): 522,139
9 percent of total population (the third most-populated department)

Santa Ana is the most northwestern department in El Salvador with Guatemala on the western and northwestern border and Honduras on the northeastern border.

Surface Water

The department of Santa Ana has many rivers and lakes that yield fresh water year-round within map units 1, 2, and 3. Rio Lempa and Rio Desague are major rivers in the department, yielding very large to enormous quantities of fresh water year-round. Smaller streams include Rio Guajoyo, Rio Tahuilapa, and Rio Suquiapa. Fresh water lakes and reservoirs, found predominantly in the northern part of the department, include Lago de Guija, Laguna de Metapan, and Embalse del Guajoyo. Most of the department, including the capital city of Santa Ana, falls within map unit 4, where fresh water is seasonally available from small intermittent streams only from early May through October. Lago de Coatepeque, in the southern part of the department, is of volcanic origin and has a high mineral content that adversely affects water quality.

Ground Water

Ground water exploration during military exercises could be considered in about 50 percent of the department, in areas of map units 1, 2, and 3. Most of map unit 1, where ground water exploration would be most favorable, is located in the southern part of the department, including the capital city of Santa Ana and some small isolated areas near Lago de Guija. The best aquifers in map unit 1 are in the upper layers of the San Salvador Formation. Other favorable areas in the department, which consist of map units 1, 2, and 3, are in the northwest part in the areas near Lago de Guija, Laguna de Metapan, and Embalse de Guajoyo.

Much of the areas north, west, and east of Metapan, and an area in the central portion of the department are not recommended for ground water exploration during military exercises. Specialized civilian technical expertise in water well drilling may have marginal success. In the southernmost part of the department, west of Lago de Coatepeque, is part of the Sierra Apaneca-Ilamatepec, occupying map unit 5 areas, where the terrain is rugged and the regional ground water table is very deep. Successful ground water exploration in much of these areas may depend upon encountering water-bearing fractures in older volcanic aquifers during drilling.

San Vicente Department

Area and relative size: $1,184\ km^2$
Eleventh out of 14 departments (5.5 percent of country)

1997 Population (est.): 155,265
3 percent of total population (one of the least-populated departments)

The department is in central El Salvador with the Pacific Ocean in the south.

Surface Water

The Rio Lempa, which has very large to enormous quantities year-round, forms the eastern border of the department. Embalse Quince de Septiembre is a major reservoir on the Rio Lempa which provides hydropower to El Salvador. Part of this reservoir, which has a capacity of 180 kilowatts, lies in the department in the northeast and has enormous quantities of fresh water available year-round. The Rio Titihuapa, which forms part of the northern boundary of the department, the lower reaches of Rio Acahuapa, and the middle reaches of Rio El Guayabo have moderate to enormous quantities of fresh water year-round. The capital city of San Vicente lies along the Rio Acahuapa. Most of the department (about 80 percent), however, has fresh water seasonally available only from early May through October, as depicted by map unit 4. The southern tip of the department, at the mouth of Rio El Guayabo at the Pacific Ocean, has very large to enormous quantities of brackish and saline water available year-round.

Ground Water

About 30 percent of the department, map units 1, 2 and 3, have areas that are favorable to moderately favorable for ground water exploration The best areas are in map units 1 and 2, located in the city proper, in a small area north of Volcan de San Vicente, in a small isolated area northeast of the city proper, and in the south.

The rest of the department lies predominantly within map units 4 and 5. These areas are not as favorable for ground water exploration, as they contain older volcanics where successful ground water exploration may depend upon encountering water-bearing fractures during drilling. Specialized civilian technical expertise in water well drilling may have marginal success, but ground water exploration during military exercises is not recommended in these areas. Brackish to saline ground water is prevalent along the coast.

Sonsonate Department

Area and relative size: 1,226 km^2
Ninth out of 14 departments (6 percent of country)

1997 Population (est.): 419,019
7 percent of total population

The department of Sonsonate, which lies in the southeastern part of the country, has abundant water resources. Sierra Apaneca-Ilamatepec, a volcanic mountain range, lies in the northern part of the department, west of Lago de Coatepeque.

Surface Water

About 15 percent of the department lies within map units 2 and 3, where the middle and lower reaches of medium-sized and smaller streams yield moderate to enormous quantities of fresh water year-round. These streams include Rio San Pedro, Rio Sensunapan, Rio Ceniza, and Rio Banderas, located in the southern part of the department. The capital city of Sonsonate is located along Rio Sensunapan, in map unit 2. The rest of the department lies predominantly in map units 4 and 5, where fresh water is seasonally available only from early May through October.

Ground Water

Sonsonate is very rich in ground water resources. About half the department lies within map units 1, 2, and 3, where ground water exploration during military exercises could be considered. The most favorable areas for ground water exploration lie within map unit 1, covering about 20 percent of the department, south of the Sierra Apaneca-Ilamatepec mountain range in the central part of the department. The capital city of Sonsonate lies in this area. Alluvial aquifers along the Rio Sensunapan and Rio Banderas are suitable for municipal and irrigation wells.

Ground water exploration during military exercises is not recommended in the rest of the department, which includes map units 4, 5, 7, and 8. Specialized civilian technical expertise in water well drilling may have marginal success but the areas of map unit 8 should be avoided due to the potential for poor quality water. The areas of map units 5 and 7 lie in the mountainous north, along the steep upper volcanic slopes, where the regional ground water table is deep and the access difficult. The aquifers in the coastal areas and the areas adjacent to Lago de Coatepeque in the northwest part of the department (map unit 8), contain brackish to saline water.

Usulutan Department

Area and relative size: 2,130 km^2
The largest department in El Salvador (10 percent of country)

1997 Population (est.): 333,077
6 percent of total population

The department of Usulutan is rich in surface and ground water resources - one of the richest departments for water resources in El Salvador.

Surface Water

The Rio Lempa, the largest and most important river in El Salvador, forms the entire western boundary of the department and has fresh water available year-round in very large to enormous quantities, as depicted by map unit 1. The southern part of the Rio Grande de San Miguel also lies in map unit 1, in the southern part of the department. A few medium-sized streams, such as Rio Los Limones and Rio El Molino lie within map units 2 and 3, and have moderate to enormous quantities of fresh water available year-round in their middle reaches. The rest of the department has fresh surface water seasonally available only from early May through October. In the coastal areas, along the Pacific Ocean and Bahia de Juquilisco, brackish and saline water is available in very large to enormous quantities year-round. Surface water near Volcan de Usulutan, in map unit 5, may have increased TDS values due to geothermal water from volcanic activity.

Ground Water

Usulutan has abundant ground water resources. Moderate to large quantities of fresh ground water are available year-round in most of the department, including the capital city of Usulutan. Except for the steep upper slopes of Volcan de Usulutan, the coastal areas, and a very small area in the northwest part of the department, ground water exploration during military exercises is recommended throughout the department. Specialized civilian technical expertise in water well drilling may have marginal success throughout the department, but the areas of map unit 8 should be avoided due to the potential for poor quality water. The best aquifers lie within the upper layers of the San Salvador Formation in map unit 1 areas. Geothermal ground water, associated with volcanic activity from Volcan de Usulutan, may contain excessive mineralization.

Table A-1. Surface Water Resources

Map Unit (See Fig. A-1)	Sources	Quantity[2]	Quality[3]	Accessibility	Remarks
1 Fresh water perennially available	Major rivers, lakes, and reservoirs year-round. **Rio Lempa basin (I)[1]:** Rio Acahuapa (1334N08839W)[4], Rio Agua Caliente (tributary to Rio Sucio) (1348N08923W), lower reaches of Rio Guajoyo (1414N08928W), Rio Lempa (1315N08849W), Rio Ostua (1417N08933W), Rio Quezalapa (1357N08900W), Rio Suquiapa (1403N08918W), Rio Sucio (1402N08917W), Rio Sumpul (1402N08848W), Rio Titihuapa (1345N08832W), and Rio Torola (1352N08830W). Major lakes include Lago de Guija (1416N08931W) and Laguna de Metapan (1419N08929W). Major reservoirs include Embalse Cerron Grande (1400N08910W), Embalse Presa Cinco de Noviembre (1358N08848W), and Embalse Quince de Septiembre (1343N08830W); all are on the Rio Lempa (1315N08849W). **Rio Goascoran basin (II):** Rio Goascoran (1325N08748W). **Rio Grande de San Miguel basin (III):** Rio Grande de San Miguel (1314N08822W), Laguna El Jocotal (1320N08815W); one major lake, Laguna Olomega (1319N08804W). **Rio Paz basin (IV):** Rio Paz (1345N09008W) and Rio Gueveapa (Rio Pampe) (1403N08952W). One lake, Laguna del Llano (1357N08952W).	Very large to enormous quantities are available year-round. Most major rivers yield very large quantities from early November through April and enormous quantities the rest of the year. Selected stream-gaging stations with minimum recorded discharges for the 1965-66, 1970-71, and 1974-80 periods of record are listed below following their corresponding hydrographic units. River flows near agricultural areas may be reduced severely by irrigation diversions during a major portion of the dry season (early November to April). **Rio Lempa basin (I):** **14** Rio Acahuapa near El Obrajuelo Lempa (1335N08840W), 64,600 L/min; **4** Rio Agua Caliente (tributary to Rio Sucio) near San Andres (1348N08924W), 43,200 L/min; **8** Upper Rio Lempa at Citala (1422N08913W), 40,000 L/min; **15** Main stem of Rio Lempa at San Marcos (1326N08842W), 3,210,000 L/min; **6** Rio Suquiapa near the mouth (1403N08918W), 131,000 L/min; **7** Rio Sucio near the mouth (1402N08917W), 258,000 L/min; **11** Rio Sumpul at Las Flores (1403N08849W), 54,300 L/min; **16** Rio Titihuapa near the mouth (1345N08832W), 87,400 L/min; **17** Rio Torola at Osicala (1350N08809W), 43,000 L/min; **9** Rio Quezalapa near the mouth (1357N08900W), 72,000 L/min; Embalse Presa Cinco de Noviembre (1358N08848W) mean regulated outflow at Embalse Presa Cinco de Noviembre (dam) (1359N08846W) is 4,500,000 L/min.	Water is generally fresh with TDS ranging from 230 to 480 mg/L. Sediment loads are heavy during the high-flow period from early May through October. Sources are biologically contaminated, especially near densely populated areas. Pollution from agricultural and industrial chemicals is also a problem. **Rio Lempa basin (I):** **14** Rio Acahuapa near El Obrajuelo Lempa (1335N08840W), pH 7.4 to 8.6 and TDS 180 to 310 mg/L; **4** Rio Agua Caliente (tributary to Rio Sucio) near San Andres (1348N08924W), pH 7.1 to 9.2 and TDS 250 to 660; **8** Upper Rio Lempa at Citala (1422N08913W), pH 7.0 to 9.0 and TDS 50 to 150; **15** Main stem of Rio Lempa at San Marcos (1326N08842W), pH 6.8 to 8.1 and TDS 60 to 180 mg/L; **6** Rio Suquiapa near the mouth (1403N08918W) pH 7.0 to 8.4 and TDS 125 to 385 mg/L; **16** Rio Titihuapa near the mouth (1345N08832W), pH 7.3 to 9.3 and TDS 80 to 205 mg/L; **7** Rio Sucio near the mouth (1402N08916W), pH 8.3 and TDS 435 mg/L; **11** Rio Sumpul at Las Flores (1403N08849W), pH 6.9 to 8.1 and TDS 152 mg/L; **17** Rio Torola at Osicala (1350N08809W), pH 7.1 to 8.2 and TDS 30 to 470 mg/L; **9** Rio Quezalapa (1357N08900W), pH 7.3 to 8.0 and TDS 155 to 220 mg/L. Lago de Guija (1416N08931W), pH 8.3. **Rio Goascoran basin (II):** **19** Rio Goascoran at Puente Goascoran; pH 8.1 and TDS 105 mg/L.	Access to and development of water points are influenced by topography and ground cover. Adverse topographic conditions that hinder access include high steep banks. After heavy rains, rivers rise rapidly and swift currents and floating debris may destroy intake equipment. Laguna de Metapan (1419N08929W) has flat low banks; however, adjacent marshy lands flood at high water. Laguna El Jocotal (1320N08815W) has flat low banks and is marshy on the northern shores. Laguna Olomega (1319N08804W) has a low shore, except on the south side where banks rise 230 m above the lake. Embalse Cinco de Noviembre (1358N08848W) has steep banks; its lowest banks are on the southeastern shore. Lago de Guija (1416N08931W) has many sandy low beaches; narrow beaches on its south shore are backed by steep hills. Access to and development of water points are feasible in populated areas and in broad flood plains.	Protection of equipment against flooding and debris is recommended. Frequent maintenance of intake equipment along channels carrying high sediment loads is recommended to counter rapid silting.

Table A-1. Surface Water Resources (Continued)

Map Unit (See Fig. A-1)	Sources	Quantity[2]	Quality[3]	Accessibility	Remarks
1 Fresh water perennially available (continued)		**Rio Goascoran basin (II):** **19** Rio Goascoran at Puente Goascoran (1336N08746W), 59,400 L/min. **Rio Grande de San Miguel basin (III):** **22** Rio Grande de San Miguel at Vado Marin (1318N08817W), 149,200 L/min; **25** Rio Grande de San Miguel below its confluence with Rio San Esteban (1331N08811W), 43,500 L/min. **Rio Paz basin (IV):** **26** Rio Paz at La Hachadura (1351N09006W), 492,000 L/min; **27** Rio Gueveapa (Rio Pampe) near San Lorenzo (1402N08947W), 90,000 L/min.	**Rio Grande de San Miguel basin (III):** **22** Rio Grande de San Miguel at Vado Marin (1318N08817W), pH 7.0 to 8.6 and TDS 40 to 450 mg/L; **25** Rio Grande de San Miguel below confluence with Rio San Esteban (1331N08811W), pH 6.9 to 8.5 and TDS 85 to 370 mg/L. Laguna Olomega (1319N08804W), pH 7.8 to 9.0 and TDS 195 to 240 mg/L. **Rio Paz basin (IV):** **26** Rio Paz at La Hachadura (1351N09006W), pH 7.1 to 8.9 and TDS 80 to 630 mg/L; **27** Rio Gueveapa (Rio Pampe) near San Lorenzo (1402N08947W), pH 7.1 to 8.0 and TDS 95 to 300 mg/L.		
2 Fresh water perennially available	**Rio Lempa basin (I):** Upper reaches of Rio Acahuapa (1334N08839W), Rio Angue (1418N08931W), Rio Copinulapa (1400N08843W), Rio Las Canas (1311N08911W), Rio El Machacal (1347N08846W), Rio El Tamarindo (1344N08825W), upper reaches of Rio Guajoyo (1414N08928W), Rio Sapo (1349N08808W), upper reaches of Rio Sucio (1402N08917W), Rio Tahuilapa (1414N08924W), Rio Talhuapa (1402N08952W), Rio Tamulasco (1402N08902), upper reaches of Rio Torola (1352N08830W). **Rio Goascoran basin (II):** Rio El Sauce (1337N08745W). **Rio Grande de San Miguel basin (III):** Rio Ereguayquin (1318N08823W),	Large to very large quantities are available year-round. Many rivers yield enormous quantities after heavy rains. Selected stream-gaging stations with minimum recorded discharges are listed below following their corresponding hydrographic units. **Rio Lempa basin (I):** **12** Rio Acahuapa at San Vicente (1338N08848W), 24,000 L/min; **1** Rio Guajoyo near Singuil (1404N08938W), 9,240 L/min; **5** Rio Sucio near San Andres (1349N08924W), 8,340 L/min; **2** Rio Angue at Los Puentes (1420N08933W), 4,740 L/min; **13** Rio Copinulapa near the mouth (1400N08843W), 15,100 L/min; **5** Rio Sucio near San Andres (1402N08916W), 8,300 L/min; **10** Rio Tamulasco near Chalatenango (1402N08856W), 5,700 L/min.	Water is generally fresh with TDS ranging from 230 to 480 mg/L. Rivers are biologically contaminated near populated areas. **Rio Lempa basin (I):** **12** Rio Acahuapa at San Vicente (1338N08848W), pH 8.0 and TDS 310 mg/L; **1** Rio Guajoyo near Singuil (1404N08938W), pH 6.9 to 8.4 and TDS 80 to 290; **5** Rio Sucio near San Andres (1349N08924W), pH 6.9 to 9.4 and TDS 260 to 660 mg/L; and **2** Rio Angue at Los Puentes (1420N08933W), pH 7.4 to 7.9 and TDS 230 to 280 mg/L; **13** Rio Copinolapa near the mouth (1400N08843W), pH 7.5 to 9.1 and TDS 70 to 205 mg/L; **10** Rio Tamulasco near Chaletenango (1402N08856W), pH 7.3 to 8.4 and TDS 70 to 195. **Rio Goascoran basin (II):** **18** Rio El Sauce near El Sauce (1340N08748W),	Access to and development of water points are feasible in populated areas and in broad flood plains.	

Table A-1. Surface Water Resources (Continued)

Map Unit (See Fig. A-1)	Sources	Quantity[2]	Quality[3]	Accessibility	Remarks
2 Fresh water perennially available (continued)	Rio Guayabal (1332N08811W), Rio San Francisco (1336N08806W), Rio Villerias (1331N08811W). **Rio Paz basin (IV):** Upper reaches of Rio Gueveapa (Rio Pampe) (1403N08952W), Rio Tacuba (1358N08959W). **Coastal areas river basins (V):** Rio Cara Sucia (1344N09002W), Rio Copinula (1358N08920W), Rio Guayapa (1341N09000W), Rio Sunzacuapa (1331N08929W). **Coastal areas river basins (VI):** Upper reaches of Rio Banderas (1332N08943W), Rio Ceniza (1336N08944W), Rio San Pedro (1336N08951W), and Rio Sensunapan (1336N08951W). **Coastal areas river basins (VII):** Rio Chilama (1329N08920W), Rio Comalapa (1325N08910W), Rio Comasagua (1329N08921W), Rio El Jute (1329N08918W), Rio Grande (1330N08923W), Rio Mizata (1331N08936W), Rio San Antonio (1329N08917W), Rio Sunzal (1329N08924W). **Rio Jiboa basin (VIII):** Upper reaches of Rio Jiboa (1322N08904W), Rio Sepaquiapa (1327N08902W). **Coastal areas river basins (IX):** Rio Jalponga (1322N08857W).	**Rio Goascoran basin (II):** **18** Rio El Sauce near El Sauce (1340N08748W), 4,800 L/min. **Coastal areas river basins (VI):** **28** Rio San Pedro at Hacienda Atalaya (1336N08950W), 29,700 L/min; **29** Rio Sensunapan at Acajutla (1335N08950W), 36,700 L/min. **Coastal areas river basins (VII):** **31** Rio Chilama at La Presa (1329N08920W), 3,400 L/min; **33** Rio Comalapa at San Luis (San Luis Talpa) (1328N08905W), 8,500 L/min. **Rio Jiboa basin (VIII):** **36** Rio Jiboa near San Ramon (1341N08856W), 2,700 L/min. **Coastal areas river basins (IX):** **37** Rio Jalponga near Santiago Nonhualco (1331N08857W), 4,200 L/min.	pH 7.2 to 8.5 and TDS 70 to 285 mg/L. **Coastal areas river basins (VI):** **28** Rio San Pedro at Hacienda Atalaya (133608950), pH 7.0 to 9.1 and TDS 100 to 290; **29** Rio Sensunapan at Acajutla (1335N08950W), pH 7.1 to 9.5 and TDS 120 to 250. **Coastal areas river basins (VII):** **31** Rio Chilama at La Presa (1329N08920W), pH 7.3 to 8.4 and TDS 100 to 265; **33** Rio Comalapa at San Luis (San Luis Talpa) (1328N08905E), pH 7.1 to 8.5 and TDS 80 to 180 mg/L. **Rio Jiboa basin (VIII):** **36** Rio Jiboa near San Ramon (1341N08856W), pH 7.3 to 7.9 and TDS 60 to 220 mg/L. **Coastal areas river basins (IX):** **37** Rio Jalponga near Santiago Nonhualco (1331N08857W), pH 7.2 to 8.2 and TDS 70 to 295 mg/L.		

Table A-1. Surface Water Resources (Continued)

Map Unit (See Fig. A-1)	Sources	Quantity[2]	Quality[3]	Accessibility	Remarks
3 Fresh water perennially available	**Rio Goascoran basin (II):** Rio Pasaquina (1332N08747W), Rio Sirama (1327N08748W). **Rio Grande de San Miguel basin (III):** Rio Grande (Rio Anamoros) (1340N08748W), Rio Gualabo (1338N08912W), Rio San Esteban (1331N08811W), Rio Taisihuat (1329N08809W). **Rio Goascoran basin (II):** Rio Pasaquina (1332N08747W), Rio Sirama (1327N08748W). **Rio Grande de San Miguel basin (III):** Rio Grande (Rio Anamoros) (1340N08748W), Rio Gualabo (1338N08912W), Rio San Esteban (1331N08811W), Rio Taisihuat (1329N08809W). **Rio Paz basin (IV):** Rio Chingo (1402N08944W). **Coastal areas river basins (VI):** Lower reaches of the Rio Banderas (1332N08943W). **Coastal areas river basins (VII):** Rio Apancoyo (1332N08940W), Rio Pululuya (1333N08942W), upper reaches of Rio Comasagua 1329N08921W), upper reaches of Rio El Jute (1329N08918W), upper reaches of Rio San Antonio (1329N08917W), upper reaches of the Rio Chilama (1329N08920W). **Coastal areas river basins (IX):** **38** Rio El Guayabo (Rio Bolsa) (1319N08847W).	Moderate to large quantities are available year-round. Rivers may yield enormous quantities after heavy rains. Selected stream-gaging stations with minimum recorded discharges are listed below following their corresponding hydrographic units. **Rio Lempa basin (I):** **3** Rio Tahuilapa about 8 km upstream from the mouth (1416N08924W), 1,140 L/min. **Rio Goascoran basin (II):** **20** Rio Pasaquina at Pasaquina (1335N08750W), 600 L/min; **21** Rio Sirama (Rio Amatillo) at Siramita (1329N08752W), 3,800 L/min. **Rio Grande de San Miguel basin (III):** **23** Rio San Esteban at La Reforma (1332N08813W), 2,800 L/min; **24** Rio Taisihuat near Hato Nuevo (1331N08809W), 1,700 L/min. **Coastal areas river basins (VI):** **30** Rio Banderas near the carreterra litoral (coastal highway) (1335N08944W), 3,500 L/min. **Coastal areas river basins (IX):** **38** Rio El Guayabo (Rio Bolsa) near the mouth (1319N08847W), 3,240 L/min.	Water is generally fresh with TDS <1,000 mg/L. Rivers and streams are biologically contaminated near populated areas. **Rio Lempa basin (I):** **3** Rio Tahuilapa about 8 km upstream from the mouth (1416N08924W), pH 7.4 to 8.1 and TDS 70 to 230 mg/L. **Rio Goascoran basin (II):** **20** Rio Pasaquina at Pasaquina (1335N08750W), pH 7.1 to 8.3 and TDS 100 to 800 mg/L. **21** Rio Sirama (Rio Amatillo) at Siramita (1329N08752W), pH 7.2 to 8.5 and TDS 70 to 365 mg/L; **Rio Grande de San Miguel basin (III):** **24** Rio Taisihuat near Hato Nuevo (1331N08809W), pH 8.5 and TDS 275 mg/L. **Coastal areas river basins (VI):** **30** Rio Banderas near the carreterra litoral (coastal highway) (1335N08944W), pH 8.1 to 9.5 and TDS 310 to 520.	Access to and development of water points are feasible in populated areas and in flood plains. Adverse topographic conditions that hinder access include high steep banks of rivers and lakes. After heavy rains, the rivers rise rapidly and swift currents and floating debris may destroy intake equipment.	Protection of equipment against flooding and debris is recommended.

Table A-1. Surface Water Resources (Continued)

Map Unit (See Fig. A-1)	Sources	Quantity[2]	Quality[3]	Accessibility	Remarks
3 Fresh water perennially available (continued)	**Coastal areas river basins (X):** Rio El Molino (1316N08827W).				
4 Fresh water seasonally available	Small rivers, small lakes, and tributaries. **Coastal areas river basins (VII):** Rio Huiza (1327N08912W).	Moderate to enormous quantities are seasonally available mainly from early May through October, but very large to enormous quantities may be available for a few days after heavy rains. Quantities decrease to meager or small as channels become dry during the dry season from November to April. **Coastal areas river basins (VII):** **32** Rio Huiza at Puente Litoral (1329N08912W), 120 L/min.	Water is generally fresh but typically high in sediment concentration. Sources may be biologically contaminated, especially near densely populated areas.	Access to and development of water points are generally difficult except in basins and lowland areas. After heavy rains, the rivers rise rapidly, and swift currents and floating debris may destroy intake equipment.	Protection of equipment against flash flooding and debris is recommended. Frequent maintenance of intake equipment along channels carrying high sediment loads is recommended to counter rapid silting.
5 Fresh water scarce or lacking	Intermittent rivers and streams on volcanoes and on steep mountain slopes.	Meager to small quantities are available from early May through October. River and stream channels are dry during the rest of the year.	Water is generally fresh, with high silt content after heavy rains. Active volcanic activity may result in local increases in TDS.	Access to and development of water points are difficult. Adverse topographic conditions that hinder access include steep relief, lack of road infrastructure, and steep banks. After heavy rains, rivers rise rapidly and swift currents and floating debris may destroy intake equipment.	Protection of equipment against flash flooding and debris is recommended.
6 Fresh water scarce or lacking	Perennial rivers, lakes, coastal lagoons, and mangroves. **Rio Lempa basin (I):** Lago de Coatepeque (1352N08933W). **Rio Paz basin (IV):** Rio Agua Caliente (1403N08952W). **Coastal areas river basins (IX, X, XI):** Mangrove swamps on Bahia de La Union (1322N08749W), Bahia de Jiquilisco (1314N08833W), and Estero de Jaltepeque (1319N08855W). **Rio Jiboa basin (VIII):** Rio Jiboa (1322N08904W), Rio El Desague (1340N08859W), and Lago de Ilopango (1340N08903W).	Moderate to enormous quantities of brackish water are available year-round. Selected stream-gaging stations with minimum recorded discharges are listed below following their corresponding hydrographic units. **Rio Paz basin (IV):** **27** Rio Agua Caliente (1403N08952W), 32,280 L/min. **Rio Jiboa basin (VIII):** **35** Rio El Desague at Desague de Ilopango (lake outlet) (1340N08900W), 12,000 L/min; **34** Rio Jiboa at Montecristo (1331N08859W), 53,400 L/min. One major lake, Lago de Ilopango (1340N08903W),	In perennial rivers and lakes, water is generally brackish with high mineral content from hydrothermal activity. In lagoons and estuaries along the Pacific coast, water is brackish or saline. Brackish water in coastal swamps is of poor quality and contains large amounts of organic materials, iron, and magnesium. **Rio Lempa basin (I):** Lago de Coatepeque (1352N08933W) at 1.5 m depth, pH 8.4, chlorides 494 mg/L, and temperature 35 °C. **Rio Jiboa basin (VIII):** **34** Rio Jiboa at Montecristo (1331N08859W), pH 7.6 to 8.5; TDS mostly 120 to 500 mg/L with a maximum of 1,165 mg/L.	Access to and development of water points are influenced by topography and ground cover. Adverse topographic conditions that hinder access include high steep banks of rivers and lakes. After heavy rains, the rivers rise rapidly and swift currents and floating debris may destroy intake equipment.	Protection of equipment from bank slumping triggered by localized flash floods is recommended.

Table A-1. Surface Water Resources (Continued)

Map Unit (See Fig. A-1)	Sources	Quantity[2]	Quality[3]	Accessibility	Remarks
6 Fresh water scarce or lacking (continued)		stores 26.8 Mm^3.	**35** Rio El Desague at Desague de Ilopango (1340N08900W), pH 8.3 and TDS 1,540 mg/L, with high levels of boron, chloride, sodium, and potassium. Lago de Ilopango basin (1340N08903W) is of volcanic origin and has high mineral content that adversely affects water quality. **Rio Paz basin (IV):** **27** Rio Agua Caliente (1403N08952W); pH 8.0 and TDS 1,485 mg/L, with high levels of boron, chloride, sodium, and potassium.		
7 Fresh water scarce or lacking	**Rio Lempa basin (I):** Rio Acelhuate (1404N08908W).	Very large quantities are available year-round. May yield enormous quantities after heavy rains. A selected stream-gaging station with minimum recorded discharges is listed below following its corresponding hydrographic unit. **Rio Lempa basin (I):** **39** Rio Acelhuate at the mouth (1404N08908W), 174,000 L/min.	Highly contaminated waters polluted with significant amounts of organic chemicals. Contaminants cannot be reliably removed by reverse osmosis treatment systems. Waters are dominated by high concentrations of domestic and industrial sewage and constitute a bio-hazard. **Rio Lempa basin (I):** **39** Rio Acelhuate at the mouth (1404N08908W), pH 8.0 and TDS 305 mg/L.	Not applicable.	Precautions should be taken to avoid contact with waters.

[1]River basin numbers are given in Roman numerals and shown in parentheses. Stream-gaging station numbers are given in Arabic numerals and shown in bold.

[2]Quantitative Terms:
- Enormous = >400,000 L/min (100,000 gal/min)
- Very large = >40,000 to 400,000 L/min (10,000 to 100,000 gal/min)
- Large = >4,000 to 40,000 L/min (1,000 to 10,000 gal/min)
- Moderate = >400 to 4,000 L/min (100 to 1,000 gal/min)
- Small = >40 to 400 L/min (10 to 100 gal/min)
- Very small = >4 to 40 L/min (1 to 10 gal/min)
- Meager = ?4 L/min (1 gal/min)

Hardness Terms:
- Soft = 0 to 60 mg/L $CaCO_3$
- Moderately hard = 61 to 120 mg/L $CaCO_3$
- Hard = 121 to 180 mg/L $CaCO_3$
- Very hard = >180 mg/L $CaCO_3$

[3]Qualitative Terms:
- Fresh water = maximum TDS ?1,000 mg/L; maximum chlorides ?600 mg/L; and maximum sulfates ?300 mg/L
- Brackish water = maximum TDS >1,000 mg/L but ?15,000 mg/L
- Saline water = TDS >15,000 mg/L

Table A-1. Surface Water Resources (Continued)

[4]Geographic coordinates list latitude first for the Northern (N) or Southern (S) Hemisphere and longitude second for the Eastern (E) or Western (W) Hemisphere. For example:

Rio Acahuapa.. (1334N08839W)

Geographic coordinates for the Rio Acahuapa that are given as 1334N08839W equal $13^0 34'$ North $88^0 39'$ West and can be written as a latitude of 13 degrees and 34 minutes north and a longitude of 88 degrees and 39 minutes west. Geographic coordinates are sufficiently accurate for locating features on the country scale map. Coordinates are approximate.

Note:

Ca	= calcium
$CaCO_3$	= calcium carbonate
gal/min	= gallons per minute
km	= kilometers
L/min	= liters per minute
mg/L	= milligrams per liter
Mm^3	= million cubic meters
m^2/d	= square meters per day
NaCl	= sodium-chloride
pH	= hydrogen-ion concentration
TDS	= total dissolved solids

Conversion Chart:

To Convert	Multiply By	To Obtain
liters per minute	0.264	gallons per minute
liters per minute	15.852	gallons per hour
liters per minute	380.517	gallons per day

Table A-2. Ground Water Resources

Map Unit (See Fig. A-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
1 Fresh water generally plentiful	Mostly volcanic aquifers of Upper Pleistocene to Recent age. Nearly all areas are in San Salvador Formation, which is at the surface where present. Volcanics consist of relatively unweathered basaltic to andesitic lavas, fractured or brecciated, interbedded with loose to moderately-compacted dust to lapilli-sized pyroclastics. Layers of mostly coarse, poorly sorted interflow alluvium are present between volcanic layers. Extremely permeable scoria basalts are locally present on the slopes of volcanoes. Aquifers are mostly unconfined.	Moderate to very large quantities. Yields may decrease during the dry season from November to April. Yields are greatest in the highly fractured to brecciated lavas and in loose, coarse-grained pyroclastics. Yields from interflow alluvial layers are moderate to large. Water levels decline 1 to 8 m during the dry season with the greatest decline in brecciated and fractured aquifers. Transmissivities of most lava flows are 100 to 500 m^2/d (8,000 to 40,000 gal/d/ft); scoria basalts are up to 10,000 m^2/d (800,000 gal/d/ft); pyroclastics are <100 m^2/d (8,000 gal/d/ft).	Fresh in most areas. Ground water and springs near geothermal areas may be brackish and have temperatures ranging from 30 to 40 ?C. Aquifers of fractured or brecciated lava flows are particularly susceptible to contamination. Because most of these aquifers are unconfined, water is transmitted rapidly in the subsurface with fractured systems able to transport the contamination in all directions.	Depth to water is 10 to 100 m. Layers of loose pyroclastics may cause oversized hole diameters if air drilling is used exclusively. High sulfates near volcanoes may cause corrosion problems. High bicarbonates near volcanoes may cause encrustation problems. PVC casing is not recommended due to seismic activity.	Areas of pyroclastics vary, with areas of coarse deposits being suitable for all but high-yield irrigation wells. Areas of relatively impermeable dust-sized pyroclastics may only be suitable for hand pump wells because of very low yields. Earthquakes may severely damage even steel-cased wells. The steeper slopes of the volcanoes which contain this aquifer are not suitable for the siting of water wells.
2 Fresh water generally plentiful	Coastal plain and alluvial aquifers consist of unconsolidated sediments. Beds of gravel and sand dominate in stream valleys and are also very common in interior basins and coastal plains. Beds of silt and clay are common in the coastal plain, less common in the interior valleys, and scarce in all but the widest stream valleys. Aquifers may be confined in interior basins and coastal plains while being unconfined elsewhere. They are typically 1 to 10 m thick in smaller valleys, 10 to 30 m thick in larger valleys, and 10 to 1,500 m thick on coastal plains, thickening toward the ocean. Consolidated sediments, lava flows, and pyroclastics underlie the aquifers.	Moderate to large quantities. Water levels decline 1 to 8 m during the dry season from November to April. The greatest declines occur at the end of the dry season and at the highest elevations above perennial streams. They are moderate to large in the western coastal plain (1335N08945W)[3]; some moderate but mostly large yields are available from the central coastal plain (1324N08850W). Transmissivities are 200 to 500 m^2/d (16,000 to 40,000 gal/d/ft).	Fresh in most areas. TDS are 250 to 1,000 mg/L but may increase with depth near geothermally active areas. Large-capacity wells near the coast may induce salt water intrusion. Biological contamination is common in shallow ground water near streams and in perched aquifers. Pesticide contamination is possible near cotton fields.	Depth to water is 2 to 50 m, increasing with elevation above perennial streams. Site accessibility is generally good. Very coarse deposits of gravel and cobble-sized material may cause excessive loss of drilling fluid. Salt water intrusion along the coast increases as the dry season progresses.	Most areas of the coastal plain are suitable for all types of wells. All alluvial aquifers are suitable for hand pump wells, and most are suitable for tactical wells. Only alluvial aquifers along the largest rivers are suitable for municipal or irrigation wells.
3 Fresh water locally plentiful	Mostly volcanic aquifers of Lower Pleistocene age in the Cuscatlan Formation. Consists of alternating beds of moderately weathered basaltic to andesitic lavas interbedded with lightly to highly compacted pyroclastics and unconsolidated alluvium.	Small to moderate quantities. Quantities decrease and depth to water increases during the dry season from November to April. Transmissivities in lavas are <100 m^2/d (8,000 gal/d/ft); pyroclastics are <50 m^2/d (4,000 gal/d/ft).	Fresh in most areas. TDS is 250 to 500 mg/L in most areas but may be locally brackish near geothermal areas. Hot brackish to saline water is possible from deeper wells in geothermally active areas. TDS and temperature increase rapidly with well depth.	Depth to water is 1 to 200 m. Access varies from easy to moderately difficult. Most areas are in plains or moderately sloped areas. Encrustation and corrosion problems are possible. PVC casing is not recommended due to	Nearly all areas are suitable for hand pump wells. Many areas are suitable for tactical wells. Locations on large fractures or at the base of volcanoes may be suitable for municipal supply or irrigation wells.

Table A-2. Ground Water Resources (Continued)

Map Unit (See Fig. A-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
3 Fresh water locally plentiful (continued)	Layers of interflow alluvium are mostly coarse and 10 to 15 m thick. Aquifers are mostly unconfined but may be partly confined.	Best areas are at the base of volcanoes or large fracture zones. The dominant fracture orientation is NW-SE. Layers of interflow alluvium form the best aquifers.	Biological contamination is common in shallow perched aquifers.	seismic activity. Salt water intrusion along the coast increases as the dry season progresses.	
4 Fresh water locally plentiful	Mostly volcanic aquifers of Pliocene and older ages. They consist of highly weathered, basaltic to andesitic lava and compacted, altered pyroclastics. Aquifers are generally unconfined.	Very small to locally moderate quantities. Quantities decrease and depth to water increases during the dry season from November to April. Transmissivities are <10 m^2/d (800 gal/d/ft). Greater yields are available locally from larger fractures. The dominant fracture orientation is NW-SE.	Fresh in nearly all areas.	Depth to water is 1 to 200 m. Access is difficult because of steep slopes, rugged narrow valleys, and lack of suitable roads.	Many valley bottoms and all major fracture sets are suitable for hand pump wells. Most areas are not suitable for other well types.
5 Fresh water scarce or lacking	Mostly volcanic aquifers of Upper Pleistocene to Recent age. Shallow perched aquifers are common at lower elevations. The aquifers are composed of fresh, basaltic to andesitic lavas which are typically fractured, brecciated, and interbedded with beds of coarse pyroclastics. Scoria basalts are also present. Areas of the San Salvador Formation are dominated by recharge and rapid outflow of available ground water. Regional ground water is unconfined with many smaller confined perched aquifers.	Small to moderate quantities from the regional ground water table. Meager quantities are possible from more shallow perched aquifers. Water levels may decline 5 m during the dry season from November to April. Most perched aquifers are seasonal.	Regional ground water table is probably brackish; however, data is lacking. Shallow perched aquifers above regional ground water are fresh, but biological contamination is common at shallowest depths. Brackish water from geothermal power plants such as those near Berlin (1330N08832W) and south of Ahuachupan (1355N08951W) may contaminate shallower ground water.	Depth to regional ground water is generally >100 m, with shallowest depths at lowest elevations. Access is difficult because of very steep and sometimes unstable slopes and lack of suitable roads. Layers of loose pyroclastics may cause oversized hole diameters if air drilling is used exclusively. Highly permeable zones may cause excessive loss of drilling fluids. Potential exists for encrustation and corrosion problems. PVC casing is not recommended due to seismic activity. Geothermal activity exists in most areas; volcanic activity is possible in some areas.	Larger perched aquifers at lower elevations may be suitable for hand pump wells. Wells in perched areas are likely to be seasonal. Generally unsuitable for all other types of wells.
6 Fresh water scarce or lacking	Mostly volcanic rocks consisting of weathered basaltic to andesitic extrusives and intrusives of Pliocene and older ages. Some areas in the vicinity of Metapan (1420N08927W) are composed of fine- to medium-grained sedimentary rocks.	Meager to small quantities of ground water are available. Large fractures yield the highest quantities. Dominant fracture orientation is NW-SE.	Ground water is fresh in nearly all areas. Biological contamination is common in perched aquifers near villages.	Depth to water is 3 to 150 m. Access is difficult in most areas because of rugged terrain and lack of suitable roads. Potential exists for encrustation and corrosion problems.	Most areas are unsuitable for hand pump or tactical wells, except where prominent fractures can be intercepted in drilling.
7 Fresh water scarce or lacking	Mostly volcanic rocks consisting of weathered basaltic to andesitic lavas and pyroclastics of Pliocene and older ages. Aquifers have very low	Meager to small quantities of ground water are available.	Ground water is fresh in nearly all areas.	Depth to water is >150 m. Access is difficult in most areas because of rugged terrain and lack of suitable roads.	Most areas are unsuitable for wells because of insufficient yields and excessive depths.

Table A-2. Ground Water Resources (Continued)

Map Unit (See Fig. A-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
7 Fresh water scarce or lacking (continued)	permeability. Recharge of the aquifers is poor since most areas are located in higher elevations than the perennial streams.				
8 Fresh water scarce or lacking	Aquifers on the coastal plain consist of unconsolidated sands, silts, and clays. Areas near Lago Ilopango (1340N08903W) and Lago Coatepeque (1352N08933W) consist of fresh to weathered volcanics that are covered in some locations by 1 to 10 m of unconsolidated sands, silts, and clays. North of the coastal plain, the Rio Jiboa valley (1322N08904W) contains a narrow alluvial aquifer with brackish water. Areas affected are adjacent to rivers and generally <10 m above the river levels.	Meager to large quantities of brackish to saline water within 2 km of the ocean, especially where surface elevations are <10 m above mean sea level.	Near Rio Jiboa, brackish water is relatively high in sulfate, chloride, and bicarbonate, and is very alkaline with a pH of up to 8.6. Saline water is dominant near Lago Ilopango and Lago Coatepeque. Ground water chemistry along the coast is similar to the chemistry of the ocean water.	Depth to water is <20 m in all areas where brackish to saline water exists. Access may be difficult near mangroves because of wet swampy soils. Access near Lago Ilopango and Lago Coatepeque is difficult because of rugged terrain and lack of suitable roads.	All areas are unsuitable for wells because of brackish or saline water. Most areas would be suitable for tactical or hand pump wells with desalination.
9 Fresh water scarce or lacking	Mostly alluvial aquifers consisting of unconsolidated sands, silts, and clays; however, a variety of aquifer characteristics exist. Unit is delineated on basis of poor water quality. Recharge is from the highly contaminated Rio Acelhuate (1403N08908W).	Moderate to large quantities of ground water are available.	Water is severely contaminated with organic compounds. Water cannot be reliably treated by reverse osmosis technology.	Ground water exploration is not recommended.	Drilling is not advisable, and installation of any type of well is not advised.

[1]Quantitative Terms:

Enormous	= >400,000 L/min (100,000 gal/min)
Very large	= >40,000 to 400,000 L/min (10,000 to 100,000 gal/min)
Large	= >4,000 to 40,000 L/min (1,000 to 10,000 gal/min)
Moderate	= >400 to 4,000 L/min (100 to 1,000 gal/min)
Small	= >40 to 400 L/min (10 to 100 gal/min)
Very small	= >4 to 40 L/min (1 to 10 gal/min)
Meager	= $\leq$4 L/min (1 gal/min)

[2]Qualitative Terms:

Fresh water	= maximum TDS $\leq$1,000 mg/L; maximum chlorides $\leq$600 mg/L; and maximum sulfates $\leq$300 mg/L
Brackish water	= maximum TDS >1,000 mg/L but $\leq$15,000 mg/L
Saline water	= TDS >15,000 mg/L

Hardness Terms:

Soft	= 0 to 60 mg/L $CaCO_3$
Moderately hard	= 61 to 120 mg/L $CaCO_3$
Hard	= 121 to 180 mg/L $CaCO_3$
Very hard	= >180 mg/L $CaCO_3$

[3]Geographic coordinates list latitude first for the Northern (N) or Southern (S) Hemisphere and longitude second for the Eastern (E) or Western (W) Hemisphere. For example:

La Union... (1320N08751W)

Geographic coordinates for La Union that are given as 1320N08751W equal 13^0 20' North 87^0 51' West and can be written as a latitude of 13 degrees and 20 minutes north and a longitude of 87 degrees and 51 minutes west. Geographic coordinates are sufficiently accurate for locating features on the country scale map. Coordinates are approximate.

Table A-2. Ground Water Resources (Continued)

Note:

$CaCO_3$	= calcium carbonate
gal/min	= gallons per minute
gal/d/ft	= gallons per day per foot
km^2	= square kilometers
L/min	= liters per minute
m^2/d	= square meters per day
mg/L	= milligrams per liter
Mm^3	= million cubic meters
PVC	= polyvinyl chloride
TDS	= total dissolved solids

Conversion Chart:

To Convert	Multiply By	To Obtain
liters per minute	0.264	gallons per minute
liters per minute	15.852	gallons per hour
liters per minute	380.517	gallons per day

Figure A-1. Surface Water Resources

SURFACE WATER RESOURCES

FRESH WATER PERENNIALLY AVAILABLE

Map unit

- **1** — Very large to enormous quantities from major streams, lakes, and reservoirs year-round.
- **2** — Large to enormous quantities from medium-sized streams from early May through October; large to very large quantities during the rest of the year.
- **3** — Moderate to enormous quantities from smaller streams from early May through October; moderate to large quantities during the rest of the year.

FRESH WATER SEASONALLY AVAILABLE

- **4** — Moderate to enormous quantities from small intermittent streams from early May through October; predominately dry during the rest of the year.

FRESH WATER SCARCE OR LACKING

- **5** — Small to large quantities from ephemeral or intermittent streams from early May through October; streams are predominately dry during the rest of the year.
- **6** — Very large to enormous quantities of brackish to saline water available from streams, lakes, coastal lagoons, and mangrove swamps year-round.
- **7** — Highly contaminated water. Presence of high levels of organic chemicals render water untreatable by reverse osmosis processes.

38▲ Stream gaging station

RIVER BASINS

- I — Rio Lempa basin
- II — Rio Goascoran basin
- III — Rio Grande de San Miguel basin
- IV — Rio Paz basin
- V — Coastal area between Rio Cara Sucia and Rio Copinula
- VI — Coastal area between Rio Sensunapan and Rio Banderas
- VII — Coastal area between Rio Pululuya and Rio Comalapa
- VIII — Rio Jiboa basin
- IX — Coastal area between Rio Jalponga and Rio El Guayabo
- X — Coastal area between Rio El Potrero and Rio Juara
- XI — Coastal area between Rio Grande de San Miguel and Rio Sirama

River basin boundary

Note: Map unit and stream gaging station numbers correspond to entries in Table A-1.

Quantitative Terms:

Enormous	= >400,000 liters per minute (L/min) (100,000 gal/min)
Very large	= >40,000 to 400,000 L/min (10,000 to 100,000 gal/min)
Large	= >4,000 to 40,000 L/min (1,000 to 10,000 gal/min)
Moderate	= >400 to 4,000 L/min (100 to 1,000 gal/min)
Small	= >40 to 400 L/min (10 to 100 gal/min)
Very small	= >4 to 40 L/min (1 to 10 gal/min)
Meager	= ≤4 L/min (1 gal/min)

Qualitative Terms:

Fresh water	= maximum total dissolved solids (TDS) <1,000 mg/L; maximum chlorides <600 mg/L; and maximum sulfates <300 mg/L
Brackish water	= maximum TDS >1,000 mg/L but <15,000 mg/L
Saline water	= TDS >15,000 mg/L

Conversion Chart:

To Convert	Multiply By	To Obtain
L/min	0.264	gallons per minute
L/min	15.852	gallons per hour
L/min	380.517	gallons per day

RECURSOS DE AGUA SUPERFICIAL

AGUA DULCE PERENNEMENTE DISPONIBLE

Unidad

- **1** — Muy grandes a enormes cantidades disponibles de ríos principales, lagos, y embalses durante todo el año.
- **2** — Grandes a enormes cantidades disponibles de ríos secundarias desde principios de mayo hasta octubre, y grandes a muy grandes cantidades disponibles durante el resto del año.
- **3** — Moderadas a enormes cantidades disponibles de ríos chicos desde principios de mayo hasta octubre, y moderadas a grandes cantidades disponibles durante el resto del año.

AGUA DULCE ESTACIONALMENTE DISPONIBLE

- **4** — Moderadas a enormes cantidades disponibles de rillitos intermitentes desde principios de mayo hasta octubre, condiciones generalmente secos durante el resto del año.

AGUA DULCE ESCASA O DEFICIENTE

- **5** — Moderadas a enormes cantidades disponibles de arroyos efimeros y rillitos intermitentes desde principios de mayo hasta octubre, condiciones generalmente secas durante el resto del año.
- **6** — Muy grandes a enormes cantidades de agua salobre o salina disponibles de ríos, lagos, lagunas costeras y en manglares durante todo el año.
- **7** — Agua muy contaminada. No se puede remediar con tratamiento de osmosis reversible por altos niveles de quimicos organicos.

38▲ Estación de Aforo Fluvial

CUENCAS FLUVIALES:

- I — Río Lempa
- II — Río Guascorán
- III — Río Grande de San Miguel
- IV — Río Paz
- V — Area costera entre los rios Cara Sucia y Copinula
- VI — Area costera entre los rios Sensunapan y Banderas
- VII — Area costera entre los rios Pululuya y Comalapa
- VIII — Río Jiboa
- IX — Area costera entre los rios Jalponga y El Guayabo
- X — Area costera entre los rios El Potrero y Juara
- XI — Area costera entre los rios Grande de San Miguel y Sirama

Límite de cuenca

Nota: Unidades numeradas del mapa refieren a los apuntes en cuadro No. A-1.

Términos Cuantitativos:

Enormes	= >400,000 litros por minuto (L/min) (100,000 gal/min)
Muy grandes	= >40,000 a 400,000 L/min (10,000 a 100,000 gal/min)
Grandes	= >4,000 a 40,000 L/min (1,000 a 10,000 gal/min)
Moderadas	= >400 a 4,000 L/min (100 a 1,000 gal/min)
Pequeñas	= >40 a 400 L/min (10 a 100 gal/min)
Muy pequeñas	= >4 a 40 L/min (1 a 10 gal/min)
Minúsculas	= <4 L/min (1 gal/min)

Términos Cualitativos:

Agua dulce	= maximo total de sólidos disueltos (TDS) <1,000 miligramos por litro (mg/L); maximo de cloruros <600 mg/L; y maximo de sulfatos <300 mg/L
Agua salobre	= maximo TDS >1,000 mg/L pero <15,000 mg/L
Agua salina	= TDS >15,000 mg/L

Tabla de Conversión:

Para Convertir	Multiplicar Por	Para Obtener
L/min	0.264	galones por minuto
L/min	15.852	galones por hora
L/min	380.517	galones por día

Figure A-2. Ground Water Resources

GROUND WATER RESOURCES

Map unit

FRESH WATER GENERALLY PLENTIFUL

1 — Moderate to very large quantities from lava flows, loose pyroclastics and interflow alluvium. Aquifers are mostly unconfined. Depth to water is 10 to 100 m.

2 — Moderate to large quantities from unconsolidated alluvium. Aquifers are mostly unconfined. Depth to water is 2 to 50 m.

FRESH WATER LOCALLY PLENTIFUL

3 — Small to moderate quantities from weathered lavas and compacted pyroclastics. Aquifers are mostly unconfined. Depth to water is 1 to 200 m.

4 — Very small to moderate quantities from lavas and compacted pyroclastics. Aquifers are mostly unconfined. Depth to water is 1 to 200 m.

FRESH WATER SCARCE OR LACKING

5 — Small to locally moderate quantities from lavas and pyroclastics from regional ground water at depths >100 m. Meager quantities available from perched, mostly seasonal aquifers. Regional aquifer is unconfined; perched aquifers are unconfined and confined.

6 — Meager to small quantities from fine- to medium-grained sedimentary rocks in some areas near Metapan and from weathered lavas and pyroclastics elsewhere. Depth to water is 3 to 150 m.

7 — Meager to small quantities from weathered lavas and pyroclastics. Depth to water is >150 m.

8 — Meager to large quantities of brackish to saline water from unconsolidated alluvium in the Pacific coastal plain and from volcanic rocks elsewhere. Areas away from the Pacific coastal plain may have elevated levels of chloride, sulfate, or bicarbonates. Depth to water is <20 m.

9 — Moderate to large quantities of severely contaminated water unfit for treatment available mainly from alluvial aquifers. Ground water is not recommended for use.

Note: Map unit numbers correspond to entries in Table A-2.

Quantitative Terms:

Enormous	= >400,000 liters per minute (L/min) (100,000 gal/min)
Very large	= >40,000 to 400,000 L/min (10,000 to 100,000 gal/min)
Large	= >4,000 to 40,000 L/min (1,000 to 10,000 gal/min)
Moderate	= >400 to 4,000 L/min (100 to 1,000 gal/min)
Small	= >40 to 400 L/min (10 to 100 gal/min)
Very small	= >4 to 40 L/min (1 to 10 gal/min)
Meager	= <4 L/min (1 gal/min)

Qualitative Terms:

Fresh water	= maximum total dissolved solids (TDS) <1,000 mg/L; maximum chlorides <600 mg/L; and maximum sulfates <300 mg/L
Brackish water	= maximum TDS >1,000 mg/L but <15,000 mg/L
Saline water	= TDS >15,000 mg/L

Conversion Chart:

To Convert	Multiply By	To Obtain
L/min	0.264	gallons per minute
L/min	15.852	gallons per hour
L/min	380.517	gallons per day

RECURSOS DE AGUA SUBTERRANEA

Unidad

AGUA DULCE GENERALMENTE ABUNDANTE

1 — Moderadas a grandes cantidades de agua dulce de flujos lávicos, y piroclásticas sueltas intercaladas con aluviónes. Acuíferos generalmente no confinados. Niveles estaticos de agua son de profundidades entre 10 a 100 metros.

2 — Moderadas a grandes cantidades de agua dulce de aluviónes no consolidados. Acuíferos generalmente no confinados. Niveles estaticos de agua son de profundidades entre 2 a 50 metros.

AGUA DULCE LOCALMENTE ABUNDANTE

3 — Pequeñas a moderadas cantidades de agua dulce de lavas descompuestas y piroclásticas compactas. Acuíferos generalmente no confinados. Niveles estaticos de agua son de profundidades entre 1 a 200 metros.

4 — Muy pequeñas a pequeñas cantidades de agua dulce de lavas y piroclásticas compactas. Acuíferos generalmente no confinados. Niveles estaticos de agua son de profundidades entre 1 a 200 metros.

AGUA DULCE ESCASA O DEFICIENTE

5 — Pequeñas a localmente moderadas cantidades de agua dulce provenientes de acuíferos regionales que consisten de lavas y piroclásticas no confinadas. Niveles estaticos de agua son de profundidades que exceden 100 metros. Escasas cantidades disponibles intermitentemente de acuiferos perchados, confinados y no confinados.

6 — Escasas a pequeñas cantidades de agua dulce. Son provenientes de rocas sedimentarias compuestas de granos finos hasta medianos en areas cerca de Metapan, y de lavas descompuestas y piroclásticas en otros lugares. Niveles estaticos de agua son de profundidades entre 3 a 150 metros.

7 — Escasas a pequeñas cantidades de agua dulce provenientes de lavas descompuestas y piroclásticas. Niveles estaticos de agua son de profundidades que exceden 150 metros.

8 — Escasas a grandes cantidades de agua salobre o salina provenientes de aluviones de la planicie costera del Pacifico y de rocas volcanicas en otros lugares. Areas fuera de la planicie costera del Pacifico se pueden contener altos niveles de cloruros, sulfatos, o bicarbonatos. Niveles estaticos de agua son de profundidades menos de 20 metros.

9 — Moderadas a grandes cantidades de agua peligrosamente contaminado de aluviones. No se recomienda el uso ni el tratamiento de este agua.

Nota: Unidades numeradas del mapa refieren a los apuntes en Cuadro No. A-2.

Términos Cuantitativos:

Enormes	= >400,000 litros por minuto (L/min) (100,000 gal/min)
Muy grandes	= >40,000 a 400,000 L/min (10,000 a 100,000 gal/min)
Grandes	= >4,000 a 40,000 L/min (1,000 a 10,000 gal/min)
Moderadas	= >400 a 4,000 L/min (100 a 1,000 gal/min)
Pequeñas	= >40 a 400 L/min (10 a 100 gal/min)
Muy pequeñas	= >4 a 40 L/min (1 a 10 gal/min)
Escasas	= ≤4 L/min (1 gal/min)

Términos Cualitativos:

Agua dulce	= maximo de totalidad de sólidos disueltos (TDS) <1,000 miligramos por litro (mg/L); maximo de cloruros <600 mg/L; y maximo de sulfatos <300 mg/L
Agua salobre	= maximo TDS >1,000 mg/L pero <15,000 mg/L
Agua salina	= TDS >15,000 mg/L

Tabla de Conversión:

Para Convertir	Multiplicar Por	Para Obtener
L/min	0.264	galones por minuto
L/min	15.852	galones por hora
L/min	380.517	galones por día