Geothermal Guatemala

Past, Present and Future Development of Geothermal Energy in Guatemala

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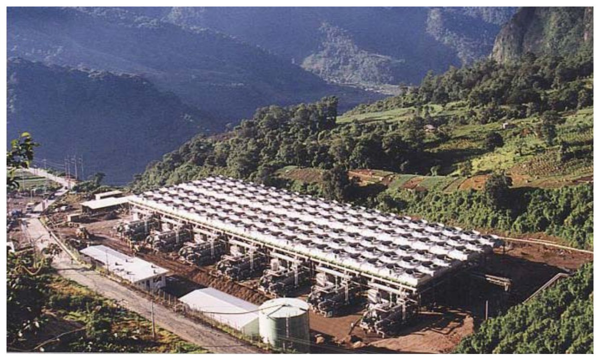
During the early 1970s, the Organization for Overseas Technical Cooperation Agency (OTCA, now the Japan International Cooperation Agency, JICA) assisted the Instituto Nacional de Electrificacin (INDE) in the assessment of Guatemala's geothermal resources. Subsequently, several projects were carried out using INDE's own funds and those of a number of financial institutions—the Inter-American Development Bank (IADB), Organization of Petroleum Export Countries (OPEC), Latin American Energy Organization (OLADE), Regional Office for Central America Programs/U.S. Agency for International Development (ROCAP/USAID), European Community, Japan International Cooperation Agency (JICA), and the International Atomic Energy Agency (IAEA).

Because of its strong surface manifestations, Moyuta (Site 12 in Fig.1) was the first area to be studied (1972). Two production-size exploration wells were drilled in the area in 1975, but disappointing downhole temperatures diverted the focus of exploration work to the Zunil, and later to the Amatitlán, geothermal areas (Sites 2 and 5 in Fig.1). After completing preliminary surface surveys, INDE drilled several slim holes in both fields.

In 1981, to improve the geothermal resource inventory for the country and establish study priorities, INDE and the Bureau de Recherches Géologiques et Minières (BRGM - France) began carrying out exploration surveys in the 13 geothermal areas shown in Figure 1, under a co-financing agreement between INDE and OLADE. All the sites are located within the southern east-west volcanic cordillera that extends across the country and covers 30 percent of Guatemala between its borders with El Salvador and Mexico.

As a result of these studies, and those carried out by OTCA in the 1970s, the Zunil and Amatitlán geothermal areas received the highest priority for further study and possible development. A somewhat lower priority was assigned to San Marcos and Tecuamburro. Lower priorities were given to Los Achiotes, Moyuta and Ixtepeque-Ipala, while the areas of Palencia, Retana, Ayarza, Atitlán and Motagua were assigned to the lowest (fourth) priority category. In 1993, with IAEA's technical cooperation, the Totonicapán geothermal area was also identified as high-priority.

Geothermal resources in Guatemala are estimated at 800 to 4,000 megawatts (MW) capacity, most likely about 1,000 MW (Lippmann, 2002). Considering that the country's current installed electricity generation capacity is 1,700 MW, geothermal energy could contribute significantly to a secure power supply to meet future electricity demands. The most serious impediment to this outcome is investor perception of risk, considering the high up front investment required to find and confirm the existence of commercial-size geothermal resources, and in the time required to amortize such investments. Unfortunately, the amortization period usually begins at a time when the

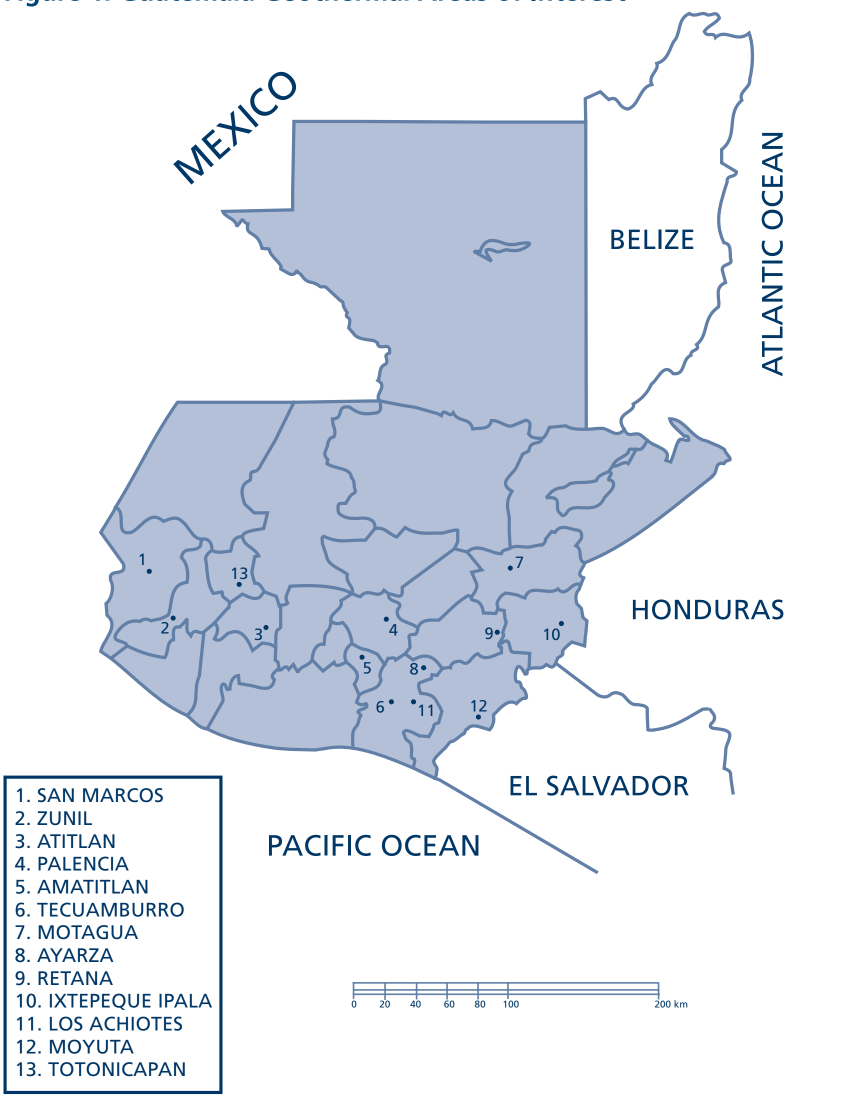


The 28.6 MW gross (24.6 MW net) binary geothermal power plant at Zunil-1 that went into commercial operation in 1999. It consists of seven identical air-cooled OEC Modules (photo courtesy of ORMAT International, Inc.)

Drilling well AMJ-2 (AMF-6J in INDE's nomenclature) at Amatitlán; Volcán de Agua is in the background.

Initial discharge of well AMJ-2 (AMF-6J in INDE's nomenclature) at Amatitlán; Volcán de Agua is in the background. The 1,700 m deep well was completed in August 2000. It was drilled with funds from a JICA grant.

Figure 1. Guatemala Geothermal Areas of Interest



characteristics and potential of a geothermal field have yet to be established, and when the real cost of operating and maintaining the field (i.e., steam cost) is unknown. In addition, it should be remembered that sound amortization and return on investment depends on the stability of the electricity market or on signing long-term power purchase agreements.

Commercial banks are reluctant to finance geothermal projects unless a substantial portion of the required amount and quality of steam has been proven. In addition, when this condition has been fulfilled, banks usually offer loans (to pay for up front and construction investments) that have short maturity periods. Moreover, in countries like Guatemala, the developer usually must pay a premium related to the "country risk." All of these obstacles discourage the utilization of geothermal energy—an indigenous renewable energy source that offers many important advantages. These include continuous availability, reduced amounts of U.S. dollars spent on fuel imports, friendliness to the environment, and the possibility of use for both generating electricity and direct geothermal applications.

Like many other developing countries, Guatemala finds it difficult to satisfy an increasing demand for public services. To alleviate the problem, the country deregulated its electricity sector, allowing private industry to participate in the business of power generation. In Central American countries where the electricity sector has been deregulated, one approach to private participation in geothermal development has been through concession arrangements initiated after a project reaches the power plant construction stage. Under this approach, governments are responsible for the up front exploration and development investments and risks. To reach the stage when steam supply or a field exploitation concession can be negotiated, governments rely on soft loans from regional development banks or grants under bilateral assistance programs. This is what Guatemala did when it negotiated steam supply and power purchase for its Zunil-I project—it used a soft IADB loan. Similarly, JICA extended a grant to enable negotiations for development of the Amatitlán geothermal resource.

It is important to remember that the purpose of grants issued under bilateral agreements in which geothermal exploration and drilling activities are involved (such as those signed by JICA) is to release governments from the burden of up front investment and risks. This results in lower concession royalties or steam supply costs, which in turn allow private investors to generate electricity at competitive prices.

Zunil Geothermal Area

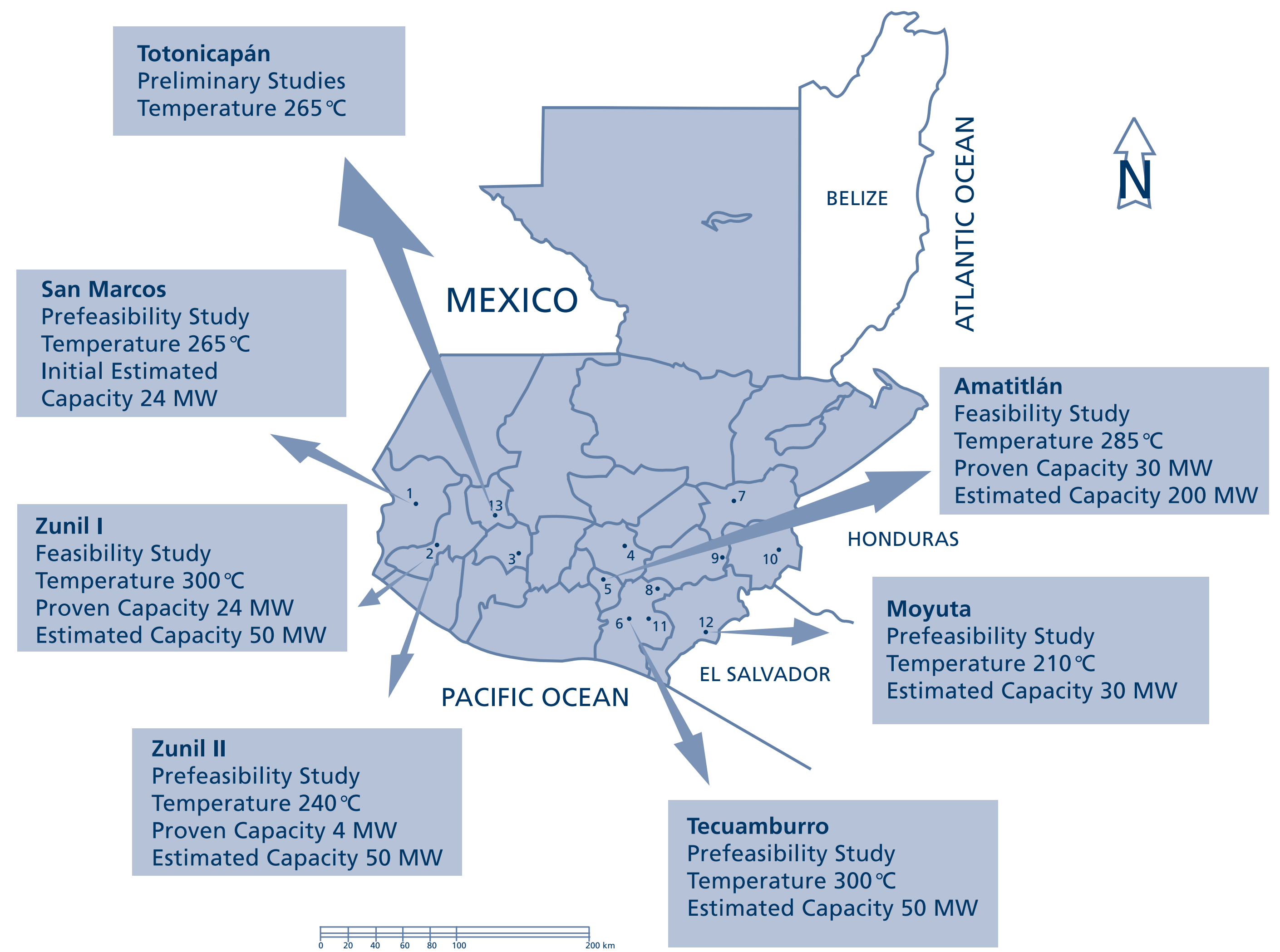
The large Zunil geothermal area (Site 2, Fig. 1), close to the southern margin of the Quetzaltenango Caldera, presents abundant and strong surface manifestations, especially at Llano del Pinal, Cantel, Almolonga, and what is known as Zunil-I and Zunil-II (Fig. 2). Although the two last areas are close to one another, separated by a deep canyon carved by the Samala River, they have different heat and geothermal fluid sources (West JEC and Telectro, 1995a; Lima Lobato and Palma, 2000).

With IADB financial assistance, the entire Zunil geothermal area was studied between 1989 and 1992. Feasibility studies were conducted at Zunil-I and prefeasibility studies at Zunil-II. Three deep exploratory wells were successfully completed at Zunil-I, adding steam to that of existing wells for a total steam production equivalent of 30 MW (Cordón y Mérida Ings. and MK-Ferguson Co., 1993). Along with the feasibility studies at Zunil-I, prefeasibility studies were conducted at Zunil-II, where two shallow slim holes and one deep small-diameter exploratory well were drilled.

Zunil-I. Based on results of its feasibility studies, INDE negotiated a Buy, Operate and Own (BOO) contract and 25-year Power Purchase Agreement (PPA) with the private sector. Under these arrangements, INDE was responsible for hot water and steam supply, wellfield operations, and adequate injection capacity. ORZUNIL-I de Electricidad Limitada won the international bid, signing a contract with INDE in late-1993. At present, 7 air-cooled, 4-MW binary power generation units are installed in the field. The power plant started commercial operations on Oct. 1, 1999.

Zunil-II. All exploratory wells drilled during pre-feasibility studies produced steam. Shallow wells tapped the steam cap of a deeper, hot-water aquifer. A deep exploration well penetrated a geothermal reservoir with high steam saturation. Short-term tests indicated that the well could produce 35 tons of dry steam per

Figure 2. Guatemala Geothermal Exploration and Development



Well at ZCQ-6 at Zunil-I during production test. The 1143 m deep well was completed in 1981 and side-tracked in 2001.

hour. Geothermal potential for Zunil-II was estimated at approximately 50 MW.

In 2001, under the auspices of the United Nations Framework Convention on Climate Change that has been signed and ratified by Guatemala, INDE submitted a formal request through the Ministry of Energy and Mines for World Bank Global Environment Facility (GEF) assistance under its initiative, "Preparation of an Institutional Framework for a Full Program for the Exploitation of the Geothermal Resources of Guatemala for Electricity Generation Projects."

The project is estimated to extend over 4 years. One of its main objectives is completion of Zunil-II feasibility studies. The GEF agreed to cofinance the initiative with the private sector. As a cosigner, INDE will contribute funds toward evaluation of the geothermal area and drilling of two production wells and one injection well, starting this year (2003). Feasibility studies will include long-term testing of the new wells, which is required to evaluate the geothermal reservoir's potential under actual operating conditions. Testing will be performed by sending steam from the producing wells to a 5-MW backpressure turbine unit. At this time, the unit is operating at Amatitlán. After the wells have been completed, the unit will be moved to Zunil-II. Under the same program, prefeasibility studies will be conducted at the Tecuamburro, San Marcos, Moyuta and Totonicapán geothermal fields (see Other Geothermal Areas).

Amatitlán Geothermal Area

From 1992 to 1995 with IADB financial assistance, INDE carried out feasibility studies at the Amatitlán Geothermal Field (Fig. 2; Roldan Manzo, 1993). Four deep exploratory wells were drilled. Two produced steam, a third showed excellent permeability but strong temperature reversals, and a fourth exhibited good temperature but low permeability. Short-term tests indicated that the two producing wells had a potential of 12 MW (West JEC and Telectro, 1995b; Lima Lobato et al., 1996; Menzies, 1996; Pham, 1996). In 1997, INDE contracted Mexico's Ingenieros Civiles Asociados (ICA) to evaluate the field (with technical support by Mexico's Comisión Federal de Electricidad - CFE), based on the exploitation of existing wells. The contract included installation and three-years operation of a 5-MW backpressure unit. The contract ended in November 2001, and the unit was dismantled.

In May 1998, JICA gave INDE a grant to carry out a project to define the extent of the Amatitlán geothermal reservoir. The project included drilling two deep, production-size exploratory wells (Lima Lobato et al., 2000; West JEC, 2001; Momita, 2002). The wells were successfully drilled, and short-term flow tests indicated that total steam produced was equivalent to 7 MW. In November 2001, INDE solicited an international bid for lease of the geothermal fields and construction of surface installations and power plant facilities. ORMAT Industries, Ltd. won the contract, which calls for gradual installation of power plant modules for a total capacity of up to 50 MW during the next 5 years.

In 2001, INDE decided to buy from CFE and reinstall the 5-MW backpressure unit that had been previously dismantled. Electricity generation began in January 2003 and will continue for 18 to 25 months. This time is needed to: 1) obtain authorization from the Ministry of Energy and Mines for the geothermal concession; 2) gain approval of the Environmental Impact Assessment from the Ministry of the Environment; and 3) complete construction of the project's turbine facilities; and 4) purchase lands and rights-of-way.

Other Geothermal Areas

Figure 2 shows areas in Guatemala where preliminary geothermal development prefeasibility and/or feasibility studies have been completed, or where slim holes and/or production-size wells have been drilled. Under the umbrella of the present GEF program for Guatemala, a strategy to select the most promising geothermal projects will be devised. The following areas were selected for completion of prefeasibility studies:

Tecuamburro Geothermal Area. The Tecuamburro geothermal area is located on the flanks of the Homonymous Volcano (Site 6, Fig.1). In 1988, pre-feasibility studies were carried out with technical assistance by the Los Alamos National Laboratory (LANL - Los Alamos, NM), using ROCAP/USAID funds (Janik et al., 1992; Goff et al., 1993). Geological, geochemical and geophysical studies were completed, and an 800 m slim hole drilled. Borehole surveys indicated a maximum temperature of 235° C. The study indicated that the field could sustain operation of a 50-MW geothermal power plant.

San Marcos Geothermal Area. The San Marcos geothermal area is northwest of Guatemala City (Site 1, Fig. 1). Based upon the regional study carried out by OLADE in 1981 (OLADE-BRGM, 1982), INDE carried out preliminary investigations over an 85 km^2 area. In 1993, INDE signed a technical and economic cooperation agreement with the European Community to perform pre-feasibility studies in the San Marcos geothermal area. Work began in September 1993, and a final report was presented in December 1997 (Comunidad Europea, 1997; Roldan Manzo, 1997). The study indicated good reservoir temperatures and suggested that the field could supply enough steam for a 24-MW geothermal power plant.

Moyuta Geothermal Area. The Moyuta geothermal area is located in the eastern part of the country (Site 12, Fig. 1). In 1974, INDE initiated regional surveys over a 1,000 km^2 region, which identified a 330 km^2 area for prefeasibility studies. In 1975, INDE gave a contract to ELC-Electroconsult to evaluate what had been done before and to carry out complementary studies (ELC-Electroconsult, 1977). As part of these studies, 12 slim holes were drilled and a prospective 10 km^2 area was selected. In 1980, production-size wells (INDE 1 and 2) were drilled, indicating maximum temperatures of around 114° C. In 1990, with the cooperation of LANL, INDE reevaluated the Moyuta geothermal system, which led to selection of promising sites for exploration drilling. The studies indicated that the probability of finding an exploitable geothermal resource to generate electricity at Moyuta is high.

Totonicapán Geothermal Area. The Totonicapán geothermal area is located near the town of Momostenango (Site 13, Fig.1). Preliminary studies were conducted with IAEA grants. In 1996, geological and geochemical field surveys were completed. Samples for isotopic analyses collected in March 1997 (Arnorsson, 1997) were analyzed by IAEA (Vienna, Austria) and a preliminary geochemical evaluation of the area was performed. In 1998, gravity and magnetometric surveys were carried out. Recent volcanism, the presence of a caldera structure, and widespread hydrothermal alteration are indicative of geologic structures that allow upward migration of hot geothermal fluids. The highest estimated geochemical temperatures are in the 200° to 230° C range. However, it is expected that even higher temperatures might be found at depth (Roldan Manzo and Ortiz Corzo, 1999).

Acknowledgments

The authors express their gratitude to the authorities of INDE, LANL, IAEA, JICA and all the other organizations that supported our work and collaborated with us in the effort to develop geothermal energy in Guatemala, and for allowing the publication of results presented in their reports. Many thanks are also extended to Marcelo Lippmann (Lawrence Berkeley National Laboratory – Berkeley, CA) and Ted Clutter (Geothermal Resources Council – Davis, CA) for their comments and assistance with the manuscript. ■

References

Arnorsson, S., 1997. *Geochemical and Isotopic Reconnaissance Survey of the Totonicapán Geothermal Field, Guatemala*. Report on an expert mission to Guatemala, on Sept. 28–Oct. 11, 1997. Science Institute, University of Iceland, Reykjavík, Iceland.

Comunidad Europea, 1997. *Estudio de Prefactibilidad del Area Geotérmica de San Marcos* (Guatemala), INDE internal report.

Cordón y Mérida Ings. and MK-Ferguson Co., 1993. *Planta Geotermoeléctrica de 15 MW, Proyecto Zunil I Quetzaltenango*. INDE internal report.

ELC-Electroconsult, 1977. *Proyecto Moyuta, Estudio de Factibilidad Preliminar*. INDE internal report.

Goff, S.J., F. Goff, F. and C.J. Janik, 1992. "Tecuamburrro Volcano, Guatemala: Exploration Geothermal Gradient Drilling and Results." *Geothermics*, v. 21, p. 483-502.

Janik, C.J., F. Goff, L. Fahlquist, A.I. Adams, A. Roldán-M., S.J. Chipera, P.E. Trujillo, and D. Counce, D., 1992. "Hydrogeochemical Exploration of Geothermal Prospects in the Tecuamburro Volcano Region, Guatemala." *Geothermics*, v. 21, p. 447-481.

Lima Lobato, E.M., T. Fujino, J.R. McNitt, R.W. Klein, R.W. Greensfelder, A. Robertson-Tait, A. Roldan, and J. Palma, 1996. "A Hydrogeological and Geochemical Model of the High-Temperature Geothermal System of Amatitlán, Guatemala." Geothermal Resources Council *Transactions*, v. 20, p. 347-352.

Lima Lobato, E.M., and J. Palma, 2000. "The Zunil-II Geothermal Field, Guatemala." *Proceedings*, World Geothermal Congress, Japan. May-June 2000, p. 2133-2138.

Lima Lobato, E.M., T. Fujino, and J.C. Palma Ayala, 2000. "Amatitlán Geothermal Field in Guatemala." Geothermal Resources Council *Bulletin*, v. 29, p. 215-220.

Lippmann, M., 2002. "Geothermal and Electricity Market in Central America." Geothermal Resources Council *Transactions*, v. 26, p. 37-42.

Menzies A. J., S.K. Sanyal, E.E. Granados, M. Pham, E.M.. Lima Lobato, A. Cuevas, and J. Torres, J., 1996. "Analysis of Well Test Data from the High-Temperature Geothermal System of Amatitlán, Guatemala." Geothermal Resources Council *Transactions*, v. 20, p. 821-827.

Momita, M., T. Fujino, E.M. Lima Lobato, and J. Palma, J. 2002. "Conceptual Model of the Amatitlan Geothermal Field, Guatemala." *Chinetsu*, v. 39, p. 11-32.

OLADE-BRGM 1982. *Estudio de Reconocimiento de los Recursos Geotérmicos de Guatemala: Informe Final*. INDE internal report.

Pham, M.P., A.J. Menzies, S.K. Sanyal, E.M. Lima Lobato, K. Shimada, J. Juárez, and H. Cuevas, 1996. "Numerical Modeling of the High-Temperature Geothermal System of Amatitlan, Guatemala." Geothermal Resources Council *Transactions*, v. 20, p. 833-838.

Roldan Manzo, A.R., 1993. *Geochemical Reevaluation of Amatitlan Geothermal Area, Guatemala*. INDE internal report.

Roldan Manzo, A.R., 1997. "Geochemical and Isotopic Evaluation of San Marcos Geothermal Area, Guatemala." *Proceedings*, 18th PNOC-EDC Geothermal Conference, Makadi City, Philippines, March 6-7, 1997, p. 377-381.

Roldan Manzo, A.R., and V. Ortiz Corzo, 1999. "Totonicapan: A New Geothermal Area in Guatemala, Central America." *Proceedings*, 20th PNOC-EDC Geothermal Conference, Makadi City, Philippines, March 4–5, 1999, p. 277-281

West JEC, 2001. *Amatitlán Geothermal Development Project: Final Report*. Japan International Cooperation Agency, INDE internal report.

West JEC and Telectro, 1995a. *Proyecto Geotérmico de Zunil II. Estudio de Pre-Factibilidad*. INDE internal report.

West JEC and Telectro, 1995b. *Proyecto Geotérmico de Amatitlán Estudio de Factibilidad*. INDE internal report.