EVALUATION OF

THE VOLCANO DISASTER ASSISTANCE PROGRAM

Guatamala, Ecuador, and the Philippines

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EXECUTIVE SUMMARY

The first purpose of this evaluation is to assess whether the objectives of the U.S. Geological Survey (USGS) Volcano Disaster Assistance Program (VDAP) have been met. These objectives are establishing self-sufficient monitoring capabilities on volcano hazards in high risk countries, and forming an international network of volcano warning. A second purpose is to provide a basis for determining whether the program should be continued and perhaps expanded.

The evaluation was based on observation, interviews and the examination of documents. The technical skills of those conducting the program were assessed by observing them at work and examining the work they produced. Equipment and software were inspected at the same time for appropriateness and maintenance. Damage resulting from volcanic eruptions, and Government and private voluntary organizations (PVO) response to it was also examined on-site.

Interviews were conducted with host country officials involved in the program; representatives of PVO's working on volcanic disasters; members of the private business community concerned with volcano risks; and Agency for International Development (A.I.D.) officials concerned with the program. Finally, various documents about program concepts. funding, and technical matters were examined.

In addition to major special assistance in dealing with the Pinatubo eruption in the Philippines, the program in the Philippines provided general assistance to five scientific centers for monitoring the changes in the activity of volcanos on a daily basis. Short-term training, technical assistance, equipment, including computers, and software were directed toward increasing the center's capacity to monitoring seismic and volcanic gas, to analyze previous eruption patterns, and to assess the likelihood and patterns of debris flows (lahars) resulting from heavy rainfall.

The evaluators found that:

(1) those conducting the program had acquired the essential skills and were well motivated and competent;

(2) training provided by the program was effective and appropriate;

(3) more training would be useful;

(4) the equipment provided by the program was appropriate and was in general, well-maintained and appropriately used;

(5) host country officials involved in the program were actively concerned with the application of the data that they produced to mitigate and prevent volcanic damage, but had limited influence on that process; and

(6) actual mitigation and prevention in regard to volcanic disasters occurs on only an irregular basis because of the nature of volcanic eruptions.

Those managing any extension of the program or any similar programs for A.I.D. should concern themselves with the application of the data and analyses developed by host government officials to efforts of disaster mitigation and prevention. Such concern should be built into the program's design.

To accomplish this objective effectively the A.I.D. Office of U.S. Foreign Assistance (OFDA) will have to use experienced personnel in or very close to disaster-prone countries in order to monitor programs such as VDAP. Training to sensitize disaster personnel to issues of how data is used to reduce casualties and damage might also be helpful.

The following additional assistance would be appropriate, subject to requirements elsewhere and geographical priorities:

(1) short-term training;

(2) long-term training of one or, perhaps, two persons per country;

(3) additional equipment, software, and providing direction, with regard to maintenance; and

(4) a modest level of technical assistance to assure that capabilities for risk management are developing further in an appropriate manner and to identify future needs.

I. PURPOSE OF THE PROJECT

In discussions with officials the Agency for International Development (A.I.D.) Office of U.S. Foreign Disaster Assistance (OFDA) in Washington, the basic purpose of the program that emerged was to develop disaster mitigation and preparedness capabilities, related to volcanic eruptions and their consequences. In the five-year agreement between OFDA and the U.S. Geological Survey (USGS), a serious effort was made to establish volcano monitoring as a long-term program and to make monitoring available worldwide. The concept of mobile teams (Volcano Crisis Assistance Teams, VCAT) remained a major component of the program, and the teams were used extensively before the project. The project permitted the expansion of the teams and the deployment of a wider range of improved sensing equipment.

The PASA agreement provided the resources for permitting the mobile teams to establish permanent local monitoring capabilities in several high risk countries: Columbia, Ecuador, Guatemala, and the Philippines.

The outputs of the project were as follows, and centered around two components:

Component 1. Mobile Response

1. Maintain a monitoring team of scientists who could respond in timely fashion to requests for assistance in assessing volcano risks.

2. Develop improved instruments for volcano monitoring.

3. Maintain volcano monitoring equipment caches for rapid deployment.

4. Establish and maintain liaison with volcanologists and other appropriate scientists in order to introduce concepts of volcanic monitoring and to facilitate the deployment of mobile teams.

Component 2. Technology Transfer

1. Conduct workshops on volcano monitoring and hazard evaluation. Develop teaching materials.

2. Provide on-going assistance in the interpretation of volcano monitoring.

3. Create databases and map-photo libraries to track and provide background on active and potentially active volcanos in selected countries.

The two components, mobile response and technology transfer, were not discrete and cannot be compartmentalized. In practice, members of the mobile teams have acted as the trainers

and have installed the technology. Both activities originated from the USGS Cascades Volcano Observatory and were staffed by the same personnel.

II. PURPOSE FOR EVALUATION

The primary purpose of the evaluation is to examine whether two general objectives of the Volcano Disaster Assistance Program (VDAP) have been met. These are to establish sustained, self-sufficient monitoring capabilities and to form an international network of monitoring and warning for volcanos. A secondary purpose of the evaluation is to assess the cost-effectiveness of the activities under the project, in order to provide a basis for deciding whether the program should be continued or expanded.

A third purpose is to identify measures that might improve the programs's efficiency and effectiveness. The evaluation included both the technical and institutional aspects of the project in each country. Columbia, although a part of the VDAP project, was not included in this evaluation because of current security concerns.

III. EVALUATION METHODOLOGY

A. Methodology

The evaluation was based on observation of working places and equipment, interviews with trained personnel, examination of documents, and discussions with persons in related fields such as disaster management to evaluate how the findings of the study were viewed. The technical skills of those conducting the program were assessed by observing them at work and examining the work they produced. Equipment and software were inspected at the same time for appropriateness and maintenance. Volcano damage sites and potential sites were also examined and interviews with affected residents shed light on their acceptance of mitigation concepts.

Interviews were conducted with host country national and local government officials involved in the program; intended beneficiaries at the village level; representatives of PVOs working on the program; members of the private business community concerned with volcano risks; and A.I.D. officials and contractors concerned with the program and other pertinent activities. Finally various documents concerning program concepts and funding and technical matters relating to the program were examined.

B. Limitations

Given the very limited time available for the evaluation and the time consumed by holidays, travel to remote sites, the natural inefficiencies of the appointment scheduling process and the need to evaluate another program (the World-Wide Earthquake Risk Management Program,

WWERM) simultaneously, the Asian team was often unable seek out objective evidence or to speak to as many people as they would have liked so as to maximize the reliability of the judgments it made and to follow up as extensively as would have been desirable on questions raised late in the visit.

This was particularly a problem with regard to impact assessment in Asia. Conclusions with regard to the effect of the program in mitigating and preventing volcanic damage are largely derivative. They are based largely on other people's judgments. Thus, though we think the result with regard to impact assessment is basically sound, it is less conclusive than we would have liked.

The South American team experienced a similar problem of shortness of time, but they were fortunate that the visit to Chile was the last of the three countries on the itinerary and there they met with Dr. Norman Banks (USGS geologist and ex-VDAP leader). Dr. Banks is the Science Advisor to the Ambassador of Chile, and Dr. Banks helped fill in numerous details both on the WWERM and VDAP projects.

IV. EVALUATION RESULTS

A. The Role of OFDA

The teams found that virtually everyone interviewed was aware of OFDA's role, and the fact it has provided funding for the projects in earthquake and volcano monitoring. Since the projects were directed by AID/W and the USGS in Vancouver, Washington, the A.I.D. missions were not familiar with details of the program. The seminars organized by the regional OFDA office in Costa Rica have helped to demonstrate OFDA's work in Latin America. Most of those interviewed felt that OFDA should make its presence more widely known and should publicize its activities. Interviews revealed that OFDA has a very positive image with those familiar with its work.

B. The Effectiveness of the USGS

Interviews in the field confirmed that USGS provided proper support to their overseas teams. There seems to be no question as to the availability of mobile teams and caches of equipment for monitoring purposes. The recent eruption of Mt. Pinatubo in the Philippines certainly confirms the rapid response from USGS based in the U.S.

The immediate outputs of the USGS projects were to provide short-term training, technical assistance, equipment, and instruction to local scientists and technicians in its use, and as an unstated purpose, assist in building scientific institutions related to volcano and earthquake monitoring. In all of these areas, USGS scientists achieved their objectives in the opinion of the two teams conducting the evaluation.

The teams interviewed professionals, who had received training, and the unanimous response was that they had benefitted from the training and the exposure to professionals in the United States. What the participants learned was directly related to thier jobs in monitoring volcanic activity. Interpreting data on seismic activity, drawing risk maps, and extending telemetric networks around volcanos are among the many skills acquired. A question asked of the trainees was whether the length of the training was either too long or too short. In general, they felt it was adequate, but most felt that they could have gained more with a somewhat longer training period, which was not quantified.

The USGS provided substantial technical assistance to the scientific institutions in the countries covered by the evaluation teams. All of the technical assistance missions were short-term, and the scientists taught principles of volcano and earthquake monitoring. Two teaching seminars held near the Galeras Volcano (in Ecuador) brought together volcanologists from Latin America, and were apparently a notable success, and praise for the seminars came from many quarters. It was unusual in that the seminar participants had an active volcano to study. In other areas, the USGS scientists worked in the developing country's seismic center or in the field. They taught local scientists how to make risk or hazard maps. They instructed participants on equipment use, helped with installation, and gave advice on maintainance. The USGS also provided parts for maintenance, either directly from their stocks or from familiar suppliers.

VDAP teaching materials used included a publication based on a three day seminar. The work entitled Volcanic Hazards and edited by Robert I. Tilling, may be used as a short course and was paid for by USGS. Another text used is Monitoring Volcanoes: Techniques and Strategies, and is reported to have been compiled by the staff of the Cascades Volcano Observatory between 1980 and 1990. In Latin America, some materials of a summary nature are reported to have been produced for governors and other officials, with translations into Spanish, in some cases.

An important contribution of VDAP was the development of the Willy Lee software for monitoring large volumes of data coming from monitoring equipment located in many different regions of the country. It was designed to run on PCs instead of mainframe computers that are used extensively in the United States. This change was requested by Dr. Norman Banks, who was the team leader of the volcano project, because he believed that PCs were the only practical approach for Third World countries where mainframe computers are too expensive. The U.S. has acquired valuable scientific data on a host of variables used in monitoring activities in Latin America. This data will help USGS scientists understand volcanic activity in the western U.S., as well as worldwide.

In the interviews, there was no criticism of USGS scientists, and their presence was much appreciated. For example, the USGS scientists took the time to explain to civil defense officials in Guatemala about the uses of risk maps, which they had assisted local scientists in developing. Project leadership appears to have been very competent. Dr. Norman Banks received praise in scientific centers in Guatemala, Ecuador, and Chile. Nevertheless, in spite

of the praise of the scientists, USGS, as an institution, did come under some criticism. There was a feeling amoung some interviewed in Latin America that USGS was working for its own purposes and not to help build scientific institutions or to help mitigate natural disasters. Some had the feeling that the scientific data was looked upon as new data for USGS scientists to use for writing papers or presenting at scientific meetings, rather than as a disaster mitigation tool to be used by the concerned country. It was difficult for the evaluators to determine the validity of this assertion. Dr. Banks expressed that he fully realized the higher purpose of the project was to save lives only after becoming project director.

C. Problems

Apart from some minor delays in the project noted by the Latin American team, no problems appear to have occurred in the implementation. In regard to equipment, it is not unusual for problems to emerge. It was not possible for the teams to visit all sites where volcano monitoring equipment is located. To the best of the knowledge of both teams, equipment was installed and is being used as evidenced by watching incoming data from functioning seismographs at volcanos. In Guatemala and Ecuador, the Latin American team made a detailed inspection of all equipment that USGS supplied to monitoring centers and can verify that, to the best of their knowledge, the wide variety of equipment is in place. In Guatemala, some monitoring equipment at volcanos has been vandalized, and the government is now building concrete block shelters around some installations.

In the Philippines, results at the output level are spotty. PVOs are interested in and by their own accounts take into consideration, risk maps supplied by PHIVOLCS in construction of temporary camps for and resettlement of displaced persons. But the government continues to construct resettlement villages in areas that may be cut off by future lahars, and engages in poorly conceived engineering works to protect roads, bridges and river banks.

Since PHIVOLCS involvement is relatively recent, more experience with the consequences of poor siting and engineering may persuade the government to pay more attention to the risks identified by PHIVOLCS. However, although recent education programs have been very successful in areas affected by eruptions, more can and should be done to educate people in the Philippines about volcanic risks, particularly lahars, and to develop more effective ways of doing so.

The design of the program was appropriate at the output level, but left something to be desired in terms of follow-through at the impact level. There was no provision in the design for any attempt to assure that the data and analyses generated by the program would be used to reduce damage or casualties from volcanic events. Admittedly, assignment of responsibility for such provision might be difficult.

D. Achievement of Purpose Underlying the PASA Agreement

The significant assumption regarding the purpose of the program was that technical assistance, training, and material support for volcanic risk management would result in the implementation of measures to reduce casualties and property damage. However, this eventual purpose or goal was not stated in the PASA agreement with USGS. Basically, the agreement listed short-term outputs such as training, technical assistance, and the acquisition of equipment. The assumptions, in general, were correct; but the higher goal of reducing casualties and damage to economic assets was not part of the agreement. Certainly, there was no guarantee that the data generated through monitors at scientific centers would be relayed to others (e.g., civil defense authorities) or used by them.

In terms of assumptions made, it appears that the USGS analyzed the realities of each country and tailored technical assistance to its needs and institutional structures. In the case of Guatemala, perhaps, more emphasis was needed in the educational process at the upper governmental level, in order to convince decision makers of the importance of minimizing casualties or material damage in a volcanic crisis. It seems that having somewhat lower expectations for the Guatemalan program compared to programs to be launched in Ecuador, Columbia, and the Philippines is an example of adjusting initial assumptions to reality.

E. Lessons Learned

Humanitarian aspects of such projects, such as saving human lives and preventing injuries, should be emphatically stated. In the design of future projects of this sort, more attention should be paid to efforts to determine whether the desired end result of the project (i.e., improved siting and engineering) is attained.

The efficacy and replicability of the systems established under the program was long ago established. The only questions remaining were whether the Philippines and other countries at similar or earlier stages of development could implement such systems and what sorts of problems might arise.

F. The Goal Of Reducing Casualties And Protecting Economic Assets

The ultimate goal of VDAP is to reduce casualties, prevent injuries, and safeguard economic assets. As discussed in this evaluation report, immediate objectives form the core of the project, but the ultimate goal, which is to be achieved, is in the future. Volcanic eruptions and the gravity of them are all defined as probabilities that may happen, say, within 5, 10, or 20 years. In order to justify OFDA expenditures on a science project, institutions must be in place to take advantage of information flowing from scientific volcano monitoring centers. These civil defense institutions must be equipped to warn affected populations of volcanic hazards and be prepared to organize assistance to people who have experienced disastrous eruptions. Examples of how the three countries have developed such institutions are discussed below.

Guatamala

Institute of Seismology, Volcanology, Meteorology and Hydrology (INSIVUMEH) section of volcanology was established to assess the risk from active volcanos on a daily basis. Although the section lacks the resources to monitor all of them, close attention is given to those considered dangerous to nearby populations. If warranted, a volcano may be placed on a state of alert, these alerts and the estimated time to a significant eruption are as follows:

yellow alert, months;
orange alert, days or weeks;
red alert, few days or hours.

The Pacaya Volcano is currently listed at an orange state of alert. In addition to seismic monitoring equipment at INSIVUMEH, two observers are stationed at the volcano, sending radio reports twice a day, provide information on the volcanos condition such as emission of ash, lava flows, deformation, and other phenomena. Daily bulletins are sent to a fairly new organization, the "Comite Nacional de Emergencies" (CONE) in regard to the volcano's condition and contain data such as number of explosions, clouds of ash, and general seismic activity. The Santiaguito Volcano is also closely monitored and has observers stationed nearby, who communicate by radio with INSIVUMEH. INSIVUMEH notifies CONE immediately if it is determined that an eruption is imminent in any volcano.

On Feb. 7, 1993, the Volcanology Section issued the following information in a bulletin to CONE for Pacaya. "In accord with the evaluation of observed phenomena and its interpretation, we consider it prudent to recommend to the National Emergency Committee the orange state of alert and of a probable strong increase in activity in the following days or weeks and of the menace to the population in the area from lava flows, falling stones, and volcanic ash. It is also recommended that CONE authorities be prepared to call an emergency before such eventualities."[1]

CONE is empowered to handle all types of emergencies, and during the last two years it has been strengthened. The President of CONE is also the Minister of National Defence. Directly under him is the Coordinator General of CONE, who manages the organization. The committee coordinates and offers direction to the activities of a host of organizations that deal directly with an emergency such as fire departments, civilian and military officials, the Red Cross, etc. Likewise, it is the government's coordinator with organizations for international assistance including AID/OFDA, UNDRO, CARE, and other official and private donors.

There are three levels of operations, which are the national committee, departmental committees, and local or municipal committees. There is no national plan for emergencies at

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[1] Boletin Vulcanologico No. 1-93, Volcan de Pacaya, INSIVUMEH.

this time; however, four plans are being developed at the departmental or provincial level. The "Plan Metropolitana" for Guatemala City will be the most comprehensive. The local committees numbering about 120 will bear a heavy load in emergencies, and CONE has been working to strengthen these committees.

The evaluation team was not in country long enough to effectively evaluate the system for preparing for national disasters but, nevertheless, tried to pick up the trail as to the effectiveness in case of threatening activity from volcanos. In starting along the trail, it appears that the relationship between INSIVUMEH and CONE is good. A question has been raised as to response time between CONE receiving an emergency report from INSIVUMEH and subsequent actions being taken.

Third parties commented that a weak relationship existed between CONE and local emergency committees, but CONE's response is that they are working to improve the local committees. Partners of the Americas has been active in helping local committees. In 1993 an effort is being made to get primary and secondary schools into emergency planning.

In the team's visit to San Vicente Pacaya, they interviewed the mayor of the town and the secretary of the local emergency committee. The community is threatened because of its close proximity to Pacaya Volcano. The impression is that the national committee is making an effort to work with the local committee, and the contacts between the two have been active. Both of them discussed the problems that they would confront in an emergency situation. The problems are too numerous to discuss in this report, but they fall into two areas. The first one is effectively informing all the affected people; and, secondly, getting the people to act. Many of them will not accept the fact that there is an emergency, and many that do are reluctant to leave for a host of reasons, for instance, one being a desire not to leave their animals behind.

One informative interview was with the head of the local emergency committee in Patracinio, which is a small village at almost the foot of Pacaya Volcano (distance 7 kms). He related the hazards they face including stones coming through the roof of his small store during an eruption. On the positive note, he said that members of the national committee have visited his town, there are plans for evacuation, and the local alarm, which is used to alert everyone, is in working order. One of the volcanologists from INSIVUMEH, who accompanied us, made it a point to inquire as to whether the alarm was working.

Getting the local populace to respond to emergencies is a problem recognized by CONE, and efforts at education have been undertaken. Whether these methods are sufficient might be questioned. In a study done through the University of San Carlos, it was found that the populace in many areas endangered by volcanos are not prepared to handle emergencies. Whatever the answer to this problem is CONE should expand efforts to educate the population to potential dangers, as well as Partners and other PVOs. Two private companies have published materials that have been distributed to affected populations.

The AID/OFDA regional office in San Jose, Costa Rica has organized seminars on responding to disasters for members of around 30 organizations paid for by P.L. 480 funds. Two seminars were held in September and December, 1992, respectively.

In order to help CONE in an emergency, an executive committee (Junta Directiva) is being established to coordinate the activities of national non-governmental organizations, international non-governmental organizations and bilateral and multilateral donors. A distinct division of labor between CONE and the Junta Directiva is not evident at present.

CONE's roles in emergencies include the following:

- identification and evaluation of the problem;
- coordination;
- evacuation;
- search and rescue;
- provision of food, water, and shelter;
- transportation;
- communication;
- management of information; and
- rehabilitation.

Ecuador

Civil Defence has come of age in Ecuador in the sense that it is fully accepted by the government as fulfilling an essential role. Ecuador is a country that has a potential for natural disasters from a number of sources. Earthquakes, volcanic eruptions, floods, and tidal waves pose ever present threats. An earthquake in 1987 caused not only considerable loss of life but also a severe economic loss from damage to oil exporting facilities. The country lost over $1 billion over the eight month period of time before output returned to normal.

Instead of a single row of active volcanoes characteristic of South America, Ecuador has a heavier concentration formed in parallel rows. Many of these volcanoes are active. Within historical times numerous eruptions have caused large losses in life and property damage. The town of Latacunga is reported to have been destroyed seven times.

In addition to Civil Defence headquarters in Quito, there are 21 regional offices one in each province. Offices are staffed by an expert in civil defense and employ up to 50 people. A coordinator directs a diverse work force, and supplies are stored for emergency use. Governors, mayors, and commanding military officers form a part of the defense network. Civil Defense has a plan for each province, and it is tailored to the type of disaster that would most likely occur. At the present time, they are trying to make the plans more comprehensive. Leading military officers from the Civil Defence in Quito coordinate projects throughout the country, in a highly centralized manner.

Training programs are very important, and about 700 people have been trained, many at the local level. Most of this training was conducted by Partners of the Americas, a PVO under an A.I.D. contract. There is a computer database listing people trained in many different fields. Interviewees were unanimous in stating that three years ago very little was done, but big improvements have occured. They attribute much of this success to the A.I.D./Partners program. The Coordinator General of Civil Defence is also a member of the high level committee that coordinates the work of government ministries and agencies.

An international department was formed in Civil Defense half a year ago with the task of coordinating international assistance in case of an emergency and in communicating with bilateral and multilateral organizations concerned with disasters. This development was the government counterpart for a large UNDRO project that has had six sub-projects. There is also a technical department, and the core staff consists of an engineer, an hydrologist, and a seismologist.

At Civil Defence, they spoke of close ties with the Instituto Geofisico at the Escuela Politecnica Nacional, which is the center of seismic monitoring. They receive daily reports on seismic events from the Instituto. Likewise they receive reports from CODEGM that monitors the activity of one volcano, Pichincha, on whose slopes the city of Quito is built; CODEGM is a government geological agency that received equipment in volcano monitoring from Italy. Since training is considered very important at Civil Defence, the UNDRO project has helped. At the beginning of March, an A.I.D.-funded pilot project was launched with the Children's Television Workshop (CTW), in order to educate children on the hazards from natural disasters. CTW is the producer of Sesame Street, and uses the same production and media techniques on this project.

Civil Defence is also building a corps of volunteers to assist in national emergencies. The program is being developed by a full- time professional, whom the team met but did not have sufficient time to interview fully. In order to store and process scientific and technical data, Civil Defence has several computers that were reportedly given by OFDA. To assist National Defence in its many activities, especially training, an accord was signed with Partners of the Americas in 1989.

In Ecuador, Partners works entirely in the area of disaster preparedness. They believe that it is imperative to obtain good scientific data regarding potential natural disasters, because it gives them a good idea as to how to plan for emergencies. In their opinion, the Instituto has provided good scientific advice including a number of risk maps. They feel that more emphasis should be placed on seismic studies for earthquake monitoring since more people have been killed by earthquakes than from volcanos. Also the seismic nets should be extended to provide better coverage of active volcanos. Partners has been promoting the training of volunteers for Civil Defence. The organization has provided money for different forms of telemetric monitoring, primarily from OFDA and P.L. 480 counterpart funds. There is a close working relationship between Partners and the Instituto. People at Civil Defence and the Instituto had a high opinion of the work done by Partners in Ecuador.

Another important project in disaster prevention and preparedness has been the UNDRO project. It has provided a wide range of assistance in the provision of equipment, technical assistance, and training. The value of the project was somewhat over a million dollars. OFDA was the largest source of funds with $654,615 being given for scientific equipment. The government of Ecuador provided $353,500, and the United Nations provided $436,000.

The purpose of the project was to address all natural disasters. It was a three year project that will end in 1993. Funds have been expended for 32 man months of international expertise, much of this for a project manager. Local experts have provided 89 man months of technical services. Training is an important part of the UNDRO project, and a seminar on the mitigation of natural disasters is planned for the end of March 1993. It will be attended by about 30 representatives of bilateral organizations and 60 from the government and other national groups.

The UNDRO project encompasses six sub-projects as follows:

- preparation and mitigation of seismic disasters in Guayaquil,
- preparation and mitigation of flooding disasters in Cuenca,
- preparation and mitigation of disasters caused by eruptions of Pichincha Volcano,
- preparation and mitigation of disasters caused by Tungurahua Volcano,
- providing protection to persons and property threatened by landslides in Quito, and
- preparing for destructive effects from tidal waves in Esmeraldas and Santa Elena.

In an interview with the project manager, who is scheduled to leave in August, 1993, he said that he believed that the project was appreciated by the government and also by people in general.

Philippines

Responsibility for volcanic risk management in the Philippines is lodged in The Philippine Institute of Volcanology and Seismology (PHIVOLCS), a semi-autonomous government agency the Director of which reports directly to the Secretary of Science and Energy. Responsibility for volcanic risk management lies with the PHIVOLCS' Volcanic Monitoring and Prediction, and Geological Disasters Awareness and Preparedness Divisions.

PHIVOLCS has a staff of approximately 180 persons of which approximately 50 are professionals. Of the professionals approximately 10 have masters degree and only one, the Director, a PhD. However another staff member is to complete his PhD this month and five more are in PhD programs. The Director of PHIVOLCS received his PhD in geology from the University of Colorado in 1960, returning home as Professor of Geology at the University of the Philippine. In 1982, he became head of the newly created PHIVOLCS.

The evaluators spoke at length over a period of several days to the those individuals working with the project and found them to be enthusiastic and proficient in their work. In addition the evaluators found that the staff concerned with volcanic risk management were concerned with the use of their analyses to mitigate risk, not merely with the analysis per se. To this purpose they are in frequent communication with members of communities affected by volcanic eruptions as well as local and national authorities. However, engineering measures such as construction of diversion dikes are in the hands of other governmental agencies.

G. Will The Results Be Sustainable?

In general, the VDAP results are sustainable. The evaluation teams believe that the establishment of a sustainable institution in each country is one of the most critical outputs of the PASA agreement with the USGS. In terms of inputs including technical assistance missions, training of scientific personnel, and the installation of equipment, these will have a lasting and positive impact on the scientific institutions in question. The power for self-sustainment has been strengthened. Each participating VDAP institution is different, and generalizing can be misleading; therefore, each is discussed separately.

In the case of Guatemala, the center for monitoring volcanos is a section of a central government organization, namely INSIVUMEH. There is competition for scarce funds, and salaries are low. The USGS has provided good assistance in developing the center into a viable institution. In 1987, there was virtually nothing. A new institution has been created, and it is self-sustaining. Nevertheless, it is relatively weak and is in need of assistance in order to insure sustainability. If one or two trained people were to leave, it would be weakened to the point of being alive but, maybe, not much more. It has no reserves of skilled manpower. There is considerable equipment in place; however, to properly monitor potentially dangerous volcanos the staff believes more is needed. Each member of the two person Latin American team felt that the Guatemalan center needs further technical assistance if it is to survive as a responsible governmental institution. Civil defense organizations are in place to take advantage of monitoring data being produced.

The Instituto Geofisico at the Escuela Politecnica Nacional in Ecuador is a strong institution. It receives support from the University (Escuela) and has a trained and loyal staff. A North American expatriate has directed the Instituto for about 20 years. Assistance from the USGS project has strengthened the center in technical areas in order to increase the level of competency in volcano monitoring, risk maps production, equipment maintenance, and high-risk volcanos studies.

The project assisted staff members in forging scientific links with volcanologists in Columbia. Of direct benefit has been assistance in equipment maintenance that has led to the development of innovative maintenance procedures and to the production of modified and improved types of antennas, which were also exported to Columbia.

H. Has The Volcano Hazards Project Attracted Other Donor Support?

In Guatemala, additional donor support has been the contribution of four modern telemetrical seismic stations employed around the Fuego Volcano, which was donated by the Swiss Relief Agency, and installed in 1992. They cooperated well with the USGS program by choosing American-made equipment and USGS-designed components to facilitate maintenance and operation of the system. Swiss scientists in volcanology make periodical missions to Guatemala to instruct professionals at INSIVUMEH, study volcanos, and assist in equipment maintenance. Some help has also come from the Centro de Prevencion de Disastres en America Central (CEPREDENAC), which is a support group funded by the Scandinavian countries, and assistance has been oriented towards the national seismic network.

In Ecuador, UNDRO has supplied money for equipment for use by the Instituto Geofisico at the University; however, OFDA has been the supplier of funds to the U.N. agency. CODIGM, an Ecuadorian government agency, with responsibility for monitoring Pichincha Volcano near Quito has received considerable equipment from the Italian development assistance agency. Unfortunately, follow-up instruction in the use of the equipment and proper maintenance is reported to be lacking.

The amounts budgeted by the Philippine government for activities of the type supported by the volcano risk program fluctuate, as they do in the U.S., according to the recency of major eruptions. Reductions in funding as time passes after the last major volcanic event affect not only the needs associated with the last eruption but long term data gathering and analytical needs as well. Nonetheless, the level of human and financial resources already devoted by the Philippine government to eruption-related activities suggest that the government will sustain the program and even expand it.

Though the PHIVOLCS has not systematically sought support for the program from other donors, support has been volunteered and provided. Given the extent and magnitude of volcanic and other natural disasters in the Philippines and the financial limitations of the government, foreign assistance will continue to be important in anticipating and responding to volcanic eruptions for some years to come.

VI. RECOMMENDATIONS

A. What Changes Should Be Made To Insure Success Of A Future Project?

As a way to introduce this section, one should say that in the opinion of many interviewed in the field, the recently completed project was considered well-oriented. USGS and the local scientific institutions achieved their stated goals. Basically the project, at least from the science standpoint, seems to have been designed correctly, especially in the sense that it was designed for assistance to local use. It was well-phased or correctly programmed, and the

performance of those involved was good. However, ways that a new project could be improved are detailed in the following paragraphs.

The evaluation teams are unanimous in recommending that OFDA should oversee project activities to a greater extent than in the past. Preferably oversight ought to be at the regional level.

If this program is extended, the PASA agreement should state that the primary goal of the project, in the long-run, is reduction of casualties and damage resulting from volcanic eruptions and that other outputs should be viewed as merely a means to this end and supplemented by the inputs necessary to make them efficacious. This goal should be written into the job description of every USGS scientist who undertakes a technical assistance mission, even though he/she may have no direct responsibility for implementing it. If everyone realizes what they are ultimately working toward, the likelihood of achieving the goal is increased.

Linkages in communication should be strengthened between the scientific organizations responsible for monitoring and the Civil Defence authorities. This recommendation is not meant to imply that the teams found any serious faults in the present systems, but there should be constant vigilance to ensure that the linkages are sound.

The USGS should contact the Swiss in regard to their activities with INSIVUMEH in Guatemala, the Italians in regard to CODIGM in Ecuador, and the French regarding seismic monitoring in Ecuador in order to coordinate scientific missions and other activities.

B. Additional Resources Recommended

Although the program has already achieved a great deal, a follow-on activity providing additional technical assistance and training, would be worthwhile to consolidate and extend to other areas the gains made by the program. Recommending budget levels is not easy given the short duration of the evaluation mission, but a modest expenditure, maybe somewhat below the previous allocation, might be a point from which to begin. In addition to assisting the individual countries, continuance of the program would insure a greater flow of data for a world-wide volcano monitoring net. This in turn will improve efforts at prediction of future eruptions, not only worldwide but also in the U.S.

Although thought was given to the countries covered in the evaluation, specific recommendations for country programs are not appropriate in this section. Nevertheless, some ideas have emerged.

Training should be continued. Initially, one or, perhaps, even two persons should receive long-term training with the goal of obtaining a master's degree in geology with specialization in volcanology or seismography. Short-term training should be provided to about two persons per country. Fields other than geology should be considered such as electronics and

computer technology. This recommendation arises from the fact that skills additional to geology are required in monitoring institutions.

Technical assistance missions should continue at a modest level by USGS scientists. Missions of one to two months apparently proved to be effective, but those of longer duration somewhat less so. Missions of less than two weeks do not seem to have been very effective because of language and cultural differences in the beginning and for a general need to become familiar with a new organization.

In order to maintain sustainability, emphasis should be placed on the proper maintenance of all equipment. The host governments should be responsible for maintaining equipment and if they fail to make funds available for parts or mobilization of maintenance crews, country support should be terminated forthwith. If a hard is not taken on this issue, bad habits will take root and the program will never be sustainable. Funds should be provided for teaching technicians equipment maintenance. Money for new equipment should be made available, but a careful assessment will should be made to determine the need for expansion of monitoring networks.

Finally, funding for the publication of risk maps should be considered. Assistance is needed, especially in Ecuador, a country that is confronted by both volcano and earthquake hazards.

ANNEX A
EVALUATING AND MONITORING VOLCANIC HAZARDS IN GUATEMALA

Institute of Seismology, Volcanology, Meteorology and Hydrology (INSIVUMEH), of the Ministry of Communications, Transport and Public Works

As a result of its geographical and geotectonical location, Guatemala is a country with a very wide range of potentially hazardous phenomena, and whose population is centered in the moderate to high hazard zones. Of primary interest to this evaluation are volcanic hazards. There are four active volcanoes in the country (out of some 40 known volcanic structures) of which Pacaya and Santiaguita are the most active with recent lava extrusions. The others, Fuego and Tacana, have fumarole activity and have shown some seismic indicators of the possibility of beginning eruptions in this decade. The volcanic hazard prevention activities under way include a telemetric seismological network, telemetric electronic tiltmeters for inflation measurements, EDM shotlines and traditional triangulation methods, geochemical evaluations of gases and fumarole minerals and geological fieldwork aimed at understanding past activity. These activities were initiated on the recommendations, and with the assistance, of the OFDA/USGS program.

There is a group of 11 people, professionals and support personnel, working in the area of volcanic hazards and a very limited budget (Q93,000 /yr). However, five years ago that budget and number of staff was only a dream. The USGS/OFDA program has been important in convincing the Guatemalan government to develop this program.
At the present time, the program is lacking a volcanic seismologist and another volcanologist oriented toward education, but this need is acknowledged both by Guatemalan officials and USGS scientists.

This group maintains and operates four telemetric seismic stations, donated by the Swiss Relief Agency in 1991, around Volcano Fuego and two around Volcano Pacaya, which are on loan from the U.S. national seismological network. This was a USGS donation after the 1976 Santa Maria earthquake that killed 23,000 people. The group makes evaluations of seismic activity correlated with observations of volcanic activity in the cone. Tiltmeter information is also continually received from these two volcanos, thanks to measurement and transmission equipment as well as personnel training given to INSEVUMHA by the VDAP and VCAT programs. Observers on or near Volcanos Pacaya and Santiaguito report, via radoio, to the Guatemalan operation center twice a day on types of activity, height of the ash column, and other phenomena.

Other activities being carried out are the manual tiltmeter measurements with the surveying equipment donated by the OFDA/USGS project. Routine geochemical sampling in the fumaroles of the two more accessible volcanoes (Pacaya and Fuego) and occasionally of Santiaguito are also part of the monitoring procedures made possible with equipment donated by USGS/OFDA.

A very important aspect of the project was the production of volcanic hazards maps for three of the four active volcanoes, done jointly between INSIVUMEH and USGS scientists. The National Emergency Committee (CONE) is reported to have copies of these. Apparently, these maps were not published as part of Stage I activities, as the INSEVUMEH directors had hoped, which should be a first priority by the Guatemalan government for phase II of this project, if it is continued.

Recently several cases of vandalism have occurred, and three seismographs from the monitoring network were affected. Personnel of INSIVUMEH have designed a vandalproof concrete house for the equipment, and the first one is projected to be built this year. Such an investment in this area shows great interest on the part of the government to protect the program. The vandalism demonstrates the magnitude of the education process needed both for cultural reasons and the presence of political antagonism in some very poor regions of the volcano district.

The basic project design seemed to have been correct, considering the low technical level and lack of experience that characterized the INSIVUMEH personnel in the area of volcanic hazards or even geological knowledge of the volcanic region of Guatemala. The Geology program of the University of San Carlos has existed for less than 10 years, and the principal focus of this has been on mineral resources, which makes sense for a developing country like Guatemala. Therefore, the USGS/OFDA program was very important in terms of opening the Guatemalan government's consciousness towards hazard evaluation, monitoring, and emergency planning.

Four phases of possibly five visualized initially were carried out between 1987 and 1992. The phases were seismic monitoring, inflation studies, direct observation monitoring on the two most active volcanos, and hazard mapping field studies for three of the four most active volcanos. Lacking were additional seismic implementation due to the lack of adequate local personnel, and the publication of volcanic hazard maps. The activities were multiple in the sense that, generally, two scientists at a time participated. For example, the program related to the installation of the seismographs or the tiltmeters was combined with the installation of the computers and the data processing methods. Strong emphasis was placed on the presence of an electronic technician, as part of the team, from the outset in order to maintain the equipment. A complete tool kit was part of the donated equipment and a fairly complete stock of spare parts.

ANNEX B
EVALUATING AND MONITORING VOLCANIC HAZARDS IN ECUADOR

Summary of Highlights of the Project.

Phase I
Began on January 1987 and finished November 1988.

First course for volcanologists on deformation monitoring in Quito (May, 1987).

OFDA/UNDRO Seminar on Volcanic Risks with George Walker in Pasto Col (August, 1987).

Installation of two telemetric seismographs, ten accel. and other equipment (August, 1988).

Second course for volcanologists on mudflows by R. Janada (September, 1989).

Phase II
Began mid-1989 and finished mid-1991, with related activities that extended to June, 1992.

Acquisition of more seismic instruments for the Coastal Seismic network, active fault mapping.

First Galeras Volcano Workshop (May-June, 1989).

Second Galeras Volcano Workshop (April-May, 1991).

Visit of ESPONA electronic group to USGS installations (CVO) (February, 1992).

Visit of ESPONA geologist to USGS installations to learn software innovations, etc. (June, 1992).

Transfer of Scientific Methodology

Phase I of the OFDA/USGS program in Ecuador initiated its two-sided program to increment the capabilities of national scientists in the area of mitigating volcanic disasters by:

1) Donating equipment which included ten seismographs and their telemetric links to the Escuela Politecnica Nacional Instituto Geofisico (ESPONA-IG) in Quito, ten accelerographs, three telemetric inclinometers and a PC between January, 1987 and August, 1988.

2) On the educational side, training sessions were given during the installation and fine tuning of the equipment. Two important regional seminars were held in Ecuador, and several Ecuadorian scientists also participated in the OFDA/USGS inspired, supported and oriented

Galeras Seminar held in Colombia, during this time. The Ecuadorian seminars given by USGS experts included one on deformation monitoring in which technicians from four Latin American countries participated and another on mudflows in which scientists from 10 countries participated. They were held in 1987 and 1988 respectively.

The fact that Volcano Guagua Pichincha, on which Quito is constructed, began to reactivate in August, 1988 was a stimulus to approve the Second Phase of VDAP in Ecuador in mid-1989. Phase II involved VDAP scientists in the establishment of a simple seismic and inclinometric network around the volcano and in which ESPONA scientists received a detailed course in hazard evaluation during a volcanic crisis.

Phase II was characterized more by the training of scientists than acquisition of equipment, although two important items were added to the Ecuadorian network during and after this phase. The training included broad participation of Ecuadorian scientists and technical support persons in the First and Second Galeras Workshops (Spring 1989 and 1991), occasional visits by USGS scientists to Ecuador, visits by members of the electronic staff to USGS installations in the U.S. to learn how to make replacement parts for seismographs and telemetric equipment (Feb. 1992), visits by a person from the geology/computer group in a similar visit to learn of the modifications in the original USGS (Willy Lee) software that had been accomplished by the USGS in the past four years in the areas of seismic event registry, analysis, and graphics (June, 1992).

In this period three experimental telemetric lahar flow detectors were installed around the Volcano Cotopaxi (May 1991) and a set of four additional PCs were given to the Institute to improve their real-time seismic event analysis capability using the new software designs (1992).

As a result of these two training sessions in the U.S., the team observed some interesting innovations in antennas and other electronic parts as well as advances in computer management of the seismic data by the ESPONA-IG group. Another important step, or series of steps, that VDAP stimulated, with help from the UNDRO program, were the termination and printing of 11 volcanic hazard maps that served as an important link between the scientific and Civil Defense groups in Ecuador.

The apparent relationship between (1) progress in the scientific sector in terms of hazard identification, monitoring, and quantification (which extended beyond ESPONA-IG to several other governmental and educational entities, thanks to OFDA/UNDRO) and (2) success in motivating a more coordinated governmental and other social agency response was the basis of the UNDRO/Japan Sasakawa Award for Hazard Mitigation given to ESPONA in May, 1992. The $45,000 prize is being used to further the work of ESPONA-IG and help sustain the operation of the Institute. Currently, central governmental funding of the University is declining.

A very important element of VDAP was the network building among Latin American geologists, geophysicists, electronics and systems people, many who were trained by the USGS or received

information in workshops sponsored by the OFDA. The majority of participants in Ecuador, as in the other countries visited, complimented the training program as effective and practical for both the educational material and technology transferred, as well as the human bonds that gave confidence to a generation of volcanological hazard monitors and evaluators in this and other regions of the world.

ANNEX C
MONITORING AND EVALUATING VOLCANIC HAZARDS IN THE PHILIPPINES

MANILA

Our evaluation of VDAP began on February 24, 1993, with a visit to PHIVOLCS Headquarters in Quezon City, where we met with PHIVOLCS director Raymundo Punongbayan and seismologist Bart Bautista.

The Philippines, with major active strike-slip faults and 21 active volcanoes, lives with potential disasters nearly every year. The 50 professionals of PHIVOLCS, although very capable and dedicated, are stretched thin to cover all aspects of prediction and remediation. Nearly all of the PHIVOLCS staff spend their time on the immediate problem or problems and have little time for research or the hazard mapping and study of prediction techniques that are so useful to a growing country like the Philippines.

PHIVOLCS is open to foreign assistance programs if they are appropriate. Their relation with the USGS-VDAP has been special, with the USGS supplying supplemental expertise for technical assistance and equipment when needed. Some of this equipment should be purchased by PHIVOLCS, but is simply too expensive. For example, a correlation spectrometer (COSPEC) is a useful tool for remotely monitoring the state of a volcano, but has a basic, no-frills price tag of $65,000. PHIVOLCS has one COSPEC, but it is being used at Pinatubo and another is needed to conduct routine measurements at the other 20 active volcanos in the country. Other assistance is available (e.g., from the Australians and Japanese), but quite often the equipment is not compatible with U.S.-supplied tools.

PHIVOLCS staff includes quite a few electrical engineers, who maintain and build equipment. Unlike most organizations, who have only scientists, PHIVOLCS recognizes the value of professionals to keep the equipment running.

The volcanologist went to Mayon Volcano, in southern Luzon, to observe the PHIVOLCS and a USGS (VDAP) collaboration in action during the eruption crisis there. The evaluation team also spent a long day with PHIVOLCS and USAID personnel at Mount Pinatubo.

MAYON VOLCANO, LEGASPI, ALBAY

Mayon Volcano is a 2400-m-high, symmetrical composite cone located in southeastern Luzon. It is part of a chain of volcanoes that follow a NW-SE trend and is located within a graben that also forms the Albay Gulf. The upper slopes of the volcano are steep, armored with welded agglutinates and lava flows. The crater is breached toward the southeast and heads the deep (100 m) Bonga gully, which channels many of the pyroclastic flows from the crater.

Activity at Mayon is usually explosive (Vulcanian), producing eruption columns with ash fallout, pyroclastic flows, lahars, and minor lava flows. The activity has mostly produced small volumes of ash, but the steep slopes of the volcano allow the rapid spread of ash and hot gas as rapidly moving (~ 100 km/hr or more) pyroclastic flows, which reach the lower flanks and spread outward at the break in slope. Fans composed of pyroclastic flow deposits are located around the volcano at the break in slope, which is at an elevation of about 800 m. The areas covered by pyroclastic flows are the most hazardous, with high-velocity, high temperature (600 to 800 degrees Celsius) destroying and burning everything in their path. The most dangerous zone is within a 6 km radius of the summit and should be declared off limits to any farming activity. The type of volcanic activity that is characteristic of past events at Mayon is very difficult to predict and the evacuation area should be kept empty until PHIVOLCS is absolutely certain that the present activity is over.

Coconut palms, tomatoes, some rice cultivation, and grazing are agricultural activities on Mayon's slopes. Farmers killed by the eruption of February 2 were in tomato fields on the middle slopes of the volcano, near the Bonga gully. Nearly 50,000 people have been evacuated from the barangays (villages) on the volcano.

Activity at Mayon has persisted through historical time. One of the most devastating eruptions occurred in 1814, when pyroclastic flows swept the slopes, killing thousands. The activity continued, with lahars (volcanic mudflows) burying the villages destroyed earlier in the eruption. A local tourist attraction is the steeple of the Cagsawa Church, which sticks out of the 1814 lahar deposits. The same deposits now form open slopes that are used for rice farming and grazing.

More recent notable eruptions occurred in 1968, 1979-1980, and 1984. Lahars buried a new real estate development along the shores of the Albay Gulf, appropriately named "The Mayon Riviera."

Although the volcano is continuously monitored for seismic activity, ground deformation, and visual observations, the present activity began with no precursory activity on February 2, 1993. A pyroclastic flow swept along the Bonga Gully, killing 75 farmers at the base of the gully. Ash fallout covered villages south of the volcano. After that eruption, additional PHIVOLCS staff were rushed to help the local observatory staff. A week later, a USGS-VDAP expert on this eruption type joined the PHIVOLCS team. Alert level 4 was established (Alert level 4 = intense unrest, low-frequency earthquakes; alert level 5 = eruption in progress). Then the waiting game began.

Mayon Observatory has three facilities; the main observatory is on Lignon Hill, adjacent to the Legaspi Airport, southeast of the volcano; remote locations, mainly for seismic instruments, are located at Sta. Miserocordia on the eastern slope, and at Mayon Resthouse on the northeastern slope.

The PHIVOLCS team and their colleague from the USGS are a smart, dedicated, and underpaid group. The job is similar to that of a fireman--long hours of observation and waiting, punctuated by moments of chaos. They are doing a great job, sharing the hard work, hopes, despair, and occasional honors. The USGS-VDAP support in this situation is that of a colleague--they supply quiet support, experience, and additional but necessary instrumentation. The USGS expert stays in the background; dealing with the civil authorities, press, and public is a PHIVOLCS responsibility.

The purpose of Mayon Observatory (and other PHIVOLCS observatories) is three-fold: (1) Scientific observation and eruption prediction; (2) Advising local and national authorities, such as disaster coordinating committees; and (3) Using the observatory to educate the public, especially schoolchildren, about volcanic hazards in general and Mayon in particular. While the volcanologist was there, approximately 50 visitors a day visited the observatory. An informed populace is one of their most important products.

Assistance during volcanic activity is readily available from the local authorities, Manila, the Philippine military (aircraft), and nongovernmental organizations. VDAP is a useful program in this complex arrangement. As a result, the authorities, press, and public are well-informed about volcano hazards and the volcano's daily state.

Professors and students at the local university (Aquinas University, Legaspi) are also involved, building a model of the volcano in the laboratory to evaluate the hydrology of the cone during the eruption.

MOUNT PINATUBO, PAMPANGA, TARLAC, NUEVA ECIJA, ZAMBALES, AND BATAAN PROVINCES

Pinatubo Volcano is part of the volcanic chain that borders the western side of central Luzon, in the Zambales Range. Before the 1991 eruption, its summit was 1745 m above sea level. Pinatubo Volcano was the home of the Aeta tribes, semi-nomadic people who raise rootcrops and bananas. On April 4, 1991, steam and ash explosions were reported by a missionary. PHIVOLCS dispatched a quick response team to make observations and to install a seismic station and distance-measuring stations.

A week later the PHIVOLCS team was joined by a USGS-VDAP team. Together, they installed a state-of-the-art, telemetered seismic and ground deformation network. Pinatubo Volcano Observatory was established at Clark Air Force Base, located at the foot of Mount Pinatubo. The joint effort, now called the Pinatubo Observatory Team, also quickly mapped the older volcanic deposits of the volcano to determine the nature and extent of previous activity.

During April and May, the geologic mapping revealed that extensive pyroclastic flows had reached the area of Angeles City and Clark Air Force Base during eruptions of Pinatubo 400 to 600 years ago. These deposits and associated lahar deposits were the basis for a volcanic hazard

map that predicted areas of devastation. The map was distributed to Philippine and U. S. authorities on May 23, 1991. The hazard planning was done as a joint effort with active participation of the National Disaster Coordinating Council and the Regional Disaster Coordinating Council. A scheme of five alert levels simplified communications between these organizations, the press, and the public.

Most officials had no ideas of the effects of volcanic eruptions. They were shown a video on volcanic hazards, prepared by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). The video, prepared specifically for this type of situation, was used to great effect in meetings with civil defense, and local and military officials. This facilitated moving people from danger zones and saved thousands of lives. Status reports came from the Pinatubo Team on a daily basis.

Between May 13 and May 28, 1991, SO_2 emissions increased ten-fold (SO_2 is a gas released from molten rock) to 5,000 tons/day, earthquakes continued at depths of 2 to 6 km, and phreatic (steam) explosions continued along a line of summit vents. On June 7, high frequency, shallow volcanic earthquakes increased to 1400/2000 per day. All indicators were that magma was rising toward the surface.

Ash eruptions began in early June, along with growth of a lava dome. The alert level was raised to 3 on June 5, to 4 on June 7, and to 5 on June 9 (5=eruption in progress). 20,000 people were moved into evacuation camps, and on June 10, 14,000 military personnel and dependents were moved from Clark Air Force Base. Eventually the number of evacuees reached 58,000.

On June 12, powerful explosive eruptions produced ash columns that rose to 19-25 km above sea level. On 14 June, and ash column reached an elevation of 30 km. Pyroclastic flows swept the mountain slopes, at speeds of 70 to 80 km/hr to distances of 15-16 km from the volcano. After June 15, activity began to decline. The total volume of volcanic ash and pumice erupted was between 7 and 9 cubic kilometers.

Serious lahar (volcanic mudflow) activity began with the rainy season in July. Volcanic ash deposits on the volcano are eroded, overloading the river systems with ash as mudflows and hyperconcentrated stream flows. These flows erode riverbanks with ease, then quickly fill channels to overflow the banks into the surrounding lowlands. This type of hazard will continue for perhaps as long as 10 years, preventing any type of resettlement in the lahar areas.

Communities along the rivers draining Mount Pinatubo were washed away or buried. 86,000 hectares of agricultural lands and fishponds were affected; this area may expand with future lahars that form during rainy seasons. All aspects of the infrastructure, including roads and water service were seriously damaged or destroyed. Including the loss of jobs following closure of the American military bases, about 651,000 people (mostly farmers) have been forced out of work.

Lahar monitoring systems run by PHIVOLCS and hazard maps prepared by the Pinatubo Observatory Team (the joint effort that is sponsored by OFDA) will prevent future loss of life, but cannot replace the lost homes or give hope for the people to return to their villages. Decisions about relocation are up to the authorities and such organizations as the Pinatubo Commission. However, PHIVOLCS staff can provide sound advice for locating future villages, factories, and utilities in this region.

The team was lucky enough to spend some time with the USAID field representative at Pinatubo, the PHIVOLCS staff at the Pinatubo Volcano Observatory, and to talk with members of the Pinatubo Commission (the multiagency group responsible for village relocation and relief). The PHIVOLCS staff is a quiet hardworking group dedicated to providing the best advice on the state of the volcano to authorities and the public.

PHIVOLCS, working with the Philippine Weather Service, is predicting lahars at Pinatubo. There are many engineering projects (dikes, culverts, etc) to direct the movement of lahars, but most appear to be futile. Many of the engineering groups in the area are not listening to the experts, who recommend complete evacuation from lahar hazard areas and a reasonable lahar warning system. Lahars are far too powerful for the engineered dikes and will either erode them in hours or less or simply fill the channels and flow into adjacent lowlands. Dams are also futile, for they are dealing with billions of cubic meters of volcanic ash. There is, however, some hope. New industries being asked to establish plants in the area and insurance companies are checking PHIVOLCS hazard maps before investing.

The Pinatubo eruption has caused untold misery for hundreds of thousands of people and billions of dollars in damage. It closed two of the largest overseas U. S. military bases. However, the equipment, training, and collaborations brought about by the small but effective VDAP effort was responsible for saving tens of thousands of lives.

SUMMARY AND RECOMMENDATIONS

PHIVOLCS and the USGS-VDAP are doing a great job and are saving lives. The program should continue, with modest increases for the purpose of:

(1) Purchase of equipment, especially a correlation spectrometer (COSPEC) and to upgrade existing equipment and software.

(2) Continuing training programs of new PHIVOLCS staff by the USGS at their observatories and offices in the U.S. This has been an effective means of technology transfer.

(3) Collaborations with the USGS and university volcanological specialists are needed during future volcanic crises or hazard mapping projects. Volcanology as a science is evolving rapidly, with new ideas and techniques being put forth every year. PHIVOLCS is a highly professional organization and can handle nearly all situations, but they are

stretched thin during eruption crises and have little time for keeping up with the latest research results.

Overall, the predictive abilities of PHIVOLCS and their VDAP colleagues have a good track record. This is respected by the Philippine authorities, the press, and the public.

NOTE ADDED IN PROOF

The March 2, 1993 Manila Bulletin's lead editorial is titled "Damage can be minimized by proper disaster preparedness." In this editorial, the government is criticized for a lack of coordinated zoning and disaster response; too many separate bureaucracies. PHIVOLCS is not criticized, but the Bulletin noted "....a major deficiency in equipment. Seismic and volcanic activities are monitored by relatively inadequate equipment."

"Since we do not foresee our country suddenly becoming "disaster-free", we need to consider taking the steps in making it "damage-ready." This can only be done if we put our heads together in creating a body that can effectively program and implement plans to reach our objectives of speedy relief and early warning measures to forewarn would-be disaster victims."

ANNEX D
PEOPLE INTERVIEWED

GUATEMALA

USAID-Guatemala City
Thomas Delany

INSIVUMEH
Eddy Sanchez, Director
E. Velazquez, Deputy Director
Otoniel Matias, Geologist/volcanologist
Rodolfo Morales, Electrical engineer
Eric Giron, Computer engineer
Rudolf De Leon, Cartographer/draftsman

CONE
Col. Alfredo Garcia Gomez, National Director

Town of San Vicente Pacaya (7 km from Volcano)
Filberto Mateo Peralta, Mayor
Eziquiel Arias, Sec. Comite de Emergencia

Village of Patrocinio (2 km from Volcano)
Villager and wife, local emergency committee

Univ. San Carlos
Arq. Jose Luis Gandara, Director-Centro de Inves. de Mitigacion de Disastres

ECUADOR

USAID-Quito
Maria Augusta Fernandez
Sonny Low
Fausto Maldonado

Escuela Politecnica Nacional-Instituto Geofisico
Minard Pete Hall, Director
Patricia Hall, Professor
Hugo Yepes, Professor
Vicinio Caseres, Electrical techician
Wilson Enriquez, Electrical engineer
Ricardo Jaramillo, Electrical engineer

Fabian Bonilla, Geologist
Juan Chamorro, Computer engineer
Alvaro Sanchez, Geologist

CODIGEM
Ing. Hernan Orillana, Director Division of Natural Risks
Ing. Renan Herrera, Chief of Geotecnical Dept.
Dr. John A. Aspen. Dir. British Geological Mission

Civil Defense
Gen. Edgar Vasconez, National Director
Fernando Molina, International Projects
Ing. Gonzalo Rivas, Chief Technical Dept.
Jorge Rodriquez Palacios, Chief Volunteer Dept.

UNDRO
Ing. Jose Briceno A., Chief Technical Advisor
Yolanda Dubois, Program official
Carlos Penaherrera Cattani, Dir. Childrens Television Workshop Project, Ecuador
Eduardo Contreras-Budge, Educator in Childrens Television Workshop Project

Partners for America
Henry Alderfer, Director
Ricardo Mena, Deputy Dir.

ORSTROM
Rene Marocco, Mission Director

PHILIPPINES

USAID-Manila

John Heard (Chief, Office of Food for Peace and Voluntary Cooperation)
José Garzon (Chief, Disaster Division and Mt. Pinatubo Coordinator)
Rodrigo Custodio (field representative and coordinator, Mt. Pinatubo area

PHIVOLCS-Manila (Philippine Institute of Volcanology and Seismology)

Dr. Ray Punongbayan (Director)

Bart Bautista (seismologist)

Private Sector-Manila

René Fortuno (Assistant Unit Manager, Luzon Regional Operations, Philippine Business for Social Progress, PSB, PVO)
Alberto Lim (director, Corporate Network for Disaster Response, trustee of The Andres Soriano Foundation, and General Manager, A. Soriano Aviation, Inc.,)
Lourdes Masing (Director, Disaster Preparedness and Relief Service, Philippine National Red Cross
Elmer Valoria (Vice President, for property insurance, Philam Insurance Co. Inc.)

PHIVOLCS-Mt. Mayon Observatory

R. Solidum, Jr. (geologist-in-charge)
R. Arboleda (geologist)
P. de los Reyes (seismologist)
J. Marcial (geophysicist)
A. Melosantos (engineer)
M. Paladio (geochemistry)
Five other staff members

USGS-Assigned to Mayon Observatory

C. Newhall (volcanologist)

Aquinas University-Legaspi

A professor of civil engineering

PHIVOLCS-Mt. Pinatubo Observatory

J. Sincocio (volcanologist in charge)
R. de la Cruz (geologist)

PARDC-Pinatubo Assistance Resettlement and Development Commission

Gen. Napoleon Angeles (Pampanga Coordinator)
Oscar Villaraiz (regional disaster coordinator)
Lt. Col. Reynaldo Lingat (Operations officer, PNP Regional Command 3)

U.S.

USGS-Cascades Volcanic Observatory

Dr. Dan Miller
Dr. Willie Scott

USGS-Denver

Dr. Thomas Casadevall

USGS-Menlo Park

Dr. Robert Tilling

Global Volcanism Network - Smithsonian Institution

Dr. Tom Simkin

INDONESIA

VSI (volcanology organization), Bandung

Wimpy Tjetjep (Director, VSI)
Dr. R. Sukhyar (Chief, Research Section, VSI)

ANNEX E
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ANNEX F
COMMENTS FROM THE FIELD