Case study of an international environmental education project

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Abstract

The Urban Waste Management and Research Foundation (UWMRF) and the College of Engineering at the University of New Orleans (UNO) have initiated several international projects to solve urban environmental problems in developing countries. One such project involved a cooperative agreement between the UNO UWMRF and the Coastal Polytechnic School (ESPOL) of Guayaquil, Ecuador, under a grant from the Ecuadorian Government. The objective of the project is to affect environmental engineering technology transfer between the US and Ecuador through undergraduate and postgraduate studies for the ESPOL faculty and students at UNO, and in-country training for Ecuadorian professionals. The Ecuadorian faculty and students in residence at UNO have prepared a technical feasibility study for the sanitary sewerage system of Guayaquil, the largest city in Ecuador, under the supervision of the UNO environmental engineering faculty.

Due to rapid population growth, the development of Guayaquil's urban sanitary infrastructure has not kept pace. The consequences of this situation put the city of Guayaquil in a state of "Sanitary Emergency." A technical feasibility study conducted at UNO uses the methodology of the international lending agencies for environmental projects. Details of the education program and the cooperative agreement between UWMRF and the government of Ecuador are discussed in this paper as an example of the way in which environmental education projects can be structured in other developing countries.

Introduction

Many developing nations are currently facing crises in environmental control due to rapidly increasing urban populations. The classical approach to solving this problem has been for the international lending agencies to fund feasibility and final design studies that are commonly executed by international consulting firms. Although these companies are usually competent, when the project activities are complete they leave the country with little technology transfer. Consequently, the local authorities are left with limited technical personnel, which is usually insufficient to handle all the required operation and maintenance tasks.

A new approach that provides practical and academic training, as well as project execution, has been successfully accomplished through a cooperative agreement between the University of New Orleans Urban Waste Management and Research Foundation (UNO-UWMRF) and the Coastal Polytechnic School (ESPOL) of Guayaquil, Ecuador. The project involved a technical feasibility study of the sanitary sewage system of Guayaquil. It included an evaluation of the existing facilities, the development of alternatives to rehabilitate the existing system, and a conceptual design alternatives for expanding the system. The project was conducted through a grant from the Ecuadorian Government.

Case Study: Guayaquil, Ecuador

Guayaquil was founded in the 16th century to protect the interests of Spain in the region. The city is in an estuary on the Pacific Ocean, bordering the Estero Salado to the south west and the Guayas River to the east. The city is surrounded by swamps that are subject to tidal effects. Guayaquil is the fourth fastest growing city in Latin America. Its population has almost tripled within the last twenty years. This large growth is population has been uncontrolled and unexpected.

The uncontrolled growth has generated subdivisions and housing that are not in accordance with any preestablished development plan. City officials are frequently unable to enforce building codes or any of the planning and zoning requirements that may exist. Unguarded or poorly secured land has been subject to invasion by squatters who construct large communities seemingly overnight (reportedly as large as 3,000 people), sometimes with indications of encouragement by corrupt politicians who have made hefty profits from these illegal ventures. These shanty villages initially consist of bamboo dwellings laid haphazardly on the ground and in certain cases through severe deforestation of the hills surrounding the city. With time, the bamboo shacks evolve into masonry dwellings and the original shanty village is transformed into an unplanned subdivision, without piped water and sewage collection facilities. There have also been several instances of "planned subdivisions" where water and sewerage have not been provided before or after construction.

A State of Sanitary Emergency

The city of Guayaquil, Ecuador is currently facing severe environmental problems that threaten the health of the population and the local and national economy. The population is expected to continue to increase every year by 12,000 families (50% of which are low income immigrants from other regions of Ecuador). At the present rate, the city will have nearly four million inhabitants by the year 2025. Consequently, the city does not have an infrastructure commensurate with the size of the population in the areas of potable water, waste water, storm water, solid wastes, telephone service, electricity, public transportation, street cleaning, street paving, etc. The development of the urban sanitary infrastructure has not kept pace with the population growth. The consequences of this situation on the environment and health of the population were such that in 1990 the Ecuadorian Central Government declared that the city of Guayaquil was in a state of "Sanitary Emergency."

In 1991, the University of New Orleans Urban Waste Management and Research Foundation (UNO-UWMRF), a nonprofit organization, was invited by the Ecuadorian Government to propose a plan for solving Guayaquil's environmental problems. A diagnosis by UNO-UWMRC [1], "Remediation of the Urban Environment of the Guayas, Ecuador Region," was prepared that included a proposal for carrying out studies to address drinking water, the sanitary sewerage system, domestic solid wastes, the urban storm sewer system, and the water quality as relating to the aquaculture industry. This report revealed severe shortcomings of the sewerage system and the catastrophic situation of the city as follows:

- Only 20% of the sewage was being collected;
- More than 40% of the city had a sewage collection system but no connections.

The disposal of raw sewage was achieved by three means: 1) underground sewers; 2) deposition in ditches and; 3) direct discharge into the Estero Salado, and the Guayas River. Clogged or collapsed sewer pipes with sewage flowing into the street are not uncommon problems. Of the eighteen existing pumping stations, none ran continuously and dysfunctional equipment and insufficient flow capacity are common. Consequently, to get rid of sewage, users connected their sewer lines to the nearest canal or storm sewer. During storm events, sewage that has accumulated in ditches is flushed to the estuaries and rivers via the storm water collection system. Many dwellings have been built near and even extend over the Esteros. The untreated waste from those dwellings along the shoreline waterways is deposited directly into the water.

Guayaquil's sewerage treatment facilities consisted of three sets of stabilization ponds that receive intermittent sewage flows when corresponding pumping stations were in operation. The existing ponds did not have the capacity to handle the 1994 flows, and, were not accomplishing any significant sewage treatment. It was estimated that less than five percent of the population was served by a secondary

sewage treatment facility (based upon population served by sewage treatment ponds divided by the population of metropolitan Guayaquil).

Long-term effects of the continued discharge of raw wastes to water courses will include potential epidemics due to contamination of the water, degradation of the water quality to make it unfit for body contact, and eutrophication of the water courses. In addition, industrial facilities discharge untreated wastes to channels that drain to the Estero Salado or directly to the rivers. To negate the impact of the discharge of raw sewage into the bodies of water within and surrounding Guayaquil, large secondary treatment plants must be planned, designed, and constructed to treat the raw waste.

Proyecto Guayaquil

Based on the UNO UWMRF report, in August 1992 the Ecuadorian Government provided financial support for a study addressing the needs of the sanitary sewerage system and entrusted this task to the technical university in Guayaquil, the Coastal Polytechnic School (ESPOL), in partnership with the UNO UWMRF. In March of 1993, an agreement was signed between ESPOL and the UNO UWMRF to perform the studies corresponding to the technical feasibility of a complete sewerage system for Guayaquil. An administrative, financial and technical framework of shared responsibility between ESPOL and the UNO UWMRF was approved by both institutions for managing "Proyecto Guayaquil."

Three Ecuadorian institutions participated in the project. These included the Coastal Polytechnic School (ESPOL) of Guayaquil, the City of Guayaquil Sewerage Board (EMAG), and the Ecuadorian Geographic Military Institute (IGM). An important component of the agreement signed by ESPOL and the UNO UWMRF was the training of Ecuadorian engineers at the University of New Orleans. Twelve professors and professionals attached to ESPOL, the City of Guayaquil Sewerage Board (EMAG), and the Ecuadorian Military Geographical Institute were selected to participate in the project as research assistants under the directions of professors and scientists at UNO. Simultaneously to receiving practical training, they were also to enroll in regular graduate courses at the University of New Orleans in the fields of environmental engineering and geographical information systems. Some students were to pursue a graduate degree program while others received specialized, non-degree training in certain technical areas.

Objectives and Scope - The main objective of the project was to conduct a technical feasibility study of the sanitary sewerage system for the City of Guayaquil in a format meeting the requirements of the international lending agencies. This included an evaluation of the existing facilities, the development of alternatives to rehabilitate the existing system, and a conceptual design of alternatives to expand the system components to meet the demand of the year 2025.

An equally important objective of this project was the technical training of Ecuadorian nationals in the environmental engineering field. Both goals together, the preparation of a conceptual sewerage system plan and personnel training at the University of New Orleans (UNO) are unique in that the project is achieved with

technology transfer. The Ecuadorian personnel involved in training had an opportunity to work on the project under the direct supervision of the UNO faculty. This approach guarantees the transfer of technology to the Ecuadorian institutions involved in the project (La Motta [2], [3]).

Background and Role of Participants - In discussing the project tasks and the role of the participants, it is important to consider some background information on the Ecuadorian institutions involved. ESPOL is a major technical Ecuadorian university located in Guayaquil. Its current student body has approximately 5,000 students and is housed in a modern and spacious campus with excellent teaching and research facilities. It provides training in the classical technical careers, such as Electrical Engineering, Electronic Engineering, Mechanical Engineering, Marine and Coastal Engineering, Oceanography, Geologic and Geotechnical Engineering, and Computer Engineering. In response to the tremendous environmental problems of Guayaquil, Civil and Environmental Engineering will be initiated shortly, but has not been taught in the past. Consequently, ESPOL needs qualified professionals to take charge of teaching and research in this area.

The academic programs of ESPOL did not include civil/sanitary engineers, and since none of the other three universities in Guayaquil offered graduate training in environmental/sanitary engineering, there was a lack of trained professionals in this field in this city. In addition, only a few of ESPOL's faculty members hold Ph.D. degrees, some have Master's degrees, but most have B. S. degrees.

The Guayaquil Sewerage Board (EMAG) has been responsible for the sewerage system for more than fifty years. Traditionally, American consulting firms have done the design work related to the sewerage system. In fact, the first sewers laid in Guayaquil were built by an American firm, and the main trunk lines still bear the names of the American engineers who participated in their construction (White, Parsons, and O'Connor Collectors). The most recent additions of the existing system were installed following the plans and specifications prepared in 1967 by Ralph M. Parsons Co. The lack of technology transfer to EMAG is thus evident.

Inadequate service charges, inflated staffing levels, and heavily politicized management have led EMAG near to bankrupt conditions, and have made it impossible to maintain and upgrade the existing sewerage facilities. Under new leadership of a new General Manager, EMAG is trying to rebuild and strengthen its technical personnel. As a first step and in agreement with ESPOL, it selected three young engineers for the training-research program at the University of New Orleans.

The Ecuadorian Geographic Military Institute (IGM) is the institution in charge of all the mapping and cartographic work done in Ecuador. Since Guayaquil is a national security area, all mapping work related to this city must be done under their direct supervision. Therefore, one engineer from IGM traveled to New Orleans with the aerial photographs of Guayaquil and was assigned to work in the project.

The international lending institutions that provide funds for construction of urban infrastructure projects in the region (Interamerican Development Bank and the World Bank) have specific requirements regarding project formulation. The UNO UWMRF has qualifications and experience on project formulation in developing

countries. Besides engineering, it includes personnel with banking experience and individuals that have actively participated in developing policies and technical manuals (La Motta [4] and [5]) that are currently being used in the Municipal Development and Infrastructure Program, funded by both IDB and the World Bank, being carried out by the Ecuadorian State Bank. Thus, the same project formulation procedures were included in the activities plan prepared by the UNO UWMRF for the Guayaquil sewerage system technical feasibility study.

The Training Component - The educational component of the project was to affect an academic exchange between UNO and ESPOL to address both the short-term and long-term needs of Ecuador. The exchange primarily focused on the enhancement of scholastic and practical training of the faculty and students in areas related to the environment. An exchange agreement was signed between UNO and ESPOL in 1991, before the Guayaquil sewerage project. This agreement covers the administrative details necessary to carry out the exchanges between the two entities. According to this agreement, the University of New Orleans will:

- Provide assistance and training to ESPOL the faculty and students to carry out the activities for Proyecto Guayaquil in Ecuador.
- Offer some Ecuadorian faculty from ESPOL the possibility of getting a Master's Degree. The ESPOL faculty enrolled in the UNO master's program were employed as research assistants for their activities on the project.

The exchange agreement and the following provisions applied to those faculty and students from ESPOL seeking advanced degrees at the University of New Orleans College of Engineering. ESPOL faculty members and participants selected for participation in this program had to meet the following requirements:

- Selection in a joint decision of the Dean of the UNO College of Engineering and the Rector of ESPOL.
- Meet all the UNO graduate school requirements for admission.
- Study a prescribed selection of courses at UNO for at least two consecutive semesters.
- Complete a research program at UNO or in Ecuador as specified by the thesis committee.
- Sign an agreement of obligation to return to ESPOL for no less than twice the time spent at UNO, after returning to Ecuador and on completion of the studies at UNO. In the case of the Sewerage Board Engineers (EMAG) who were originally selected by ESPOL, they would work for EMAG upon their return to Ecuador.

The training that the Ecuadorian engineers received at the University of New Orleans under the Guayaquil sewerage project was both academic and practical. Eight of the twelve original participants have received a Master's degree with a

concentration in Civil and Environmental Engineering. Two additional participants are continuing their graduate programs at UNO.

As a result of this project, Ecuadorian nationals have received both practical and academic training in environmental engineering and in geographic information systems. Seven participants from ESPOL staff can pass on new knowledge to their students, and the others will use their new skills in doing their daily tasks at the respective institutions in Ecuador.

Project Task Groups - The project was organized unto the following groups in Guayaquil and in New Orleans to perform the project tasks (4):

- A field team to evaluate the sewerage system network. The team organized by ESPOL to work in Guayaquil was divided into four groups. The first evaluated house connections; the second reviewed the existing sewer pipe, 15" in diameter and larger; the third reviewed the individual excreta disposal systems; and the fourth group worked on flow measurements.

- A team for doing the hydraulic evaluation and the conceptual design of the sewerage system network. This team included one engineer from EMAG and three engineers from ESPOL, all working at UNO as graduate research assistants. The tasks developed by this group included a conceptual design of short-term measures for the sewer system rehabilitation, and a conceptual design of the sewer system expansions to meet the demand at the end of the design period. Computer software, developed by a private consultant in Ecuador for this task, was tailored to the needs of the Guayaquil project and proved to be a valuable tool for the hydraulic analysis of the sewer system.

- A field team for evaluating the sewage treatment plants, organized by ESPOL, and working in Guayaquil. This team did both a physical and a performance evaluation of the existing treatment facilities.

- A team for analyzing the capacity and design of the sewage treatment plants included one engineer from ESPOL working at UNO, one UNO staff member, and one graduate student from UNO. This team was in charge of three main tasks, running an anaerobic wastewater treatment pilot plant, developing a conceptual design for the short term measures to rehabilitate the treatment plants, and doing the preliminary designs of the waste treatment facilities needed for the end of the design period.

- A field team to evaluate the existing pumping stations (ESPOL, Guayaquil).

- A team for evaluating the hydraulic capacity and the design of the pumping stations, which included a UNO staff member and an ESPOL engineer working at UNO. The tasks of this group included preparation of a conceptual design of the short-term measures needed to attain continuous

operation of the eighteen existing pumping stations, and planning the expansions needed to meet the demand at the end of the design period.

- A field topography team (ESPOL, Guayaquil) in charge of providing ground and sewer invert elevations, and general dimensions of the sewerage system.

- A UNO team for mapping and for the geographic information system (GIS), consisting of one engineer from IGM, two engineers from EMAG, three ESPOL engineers, and eight undergraduate assistants, all working at UNO. The tasks of this group included the preparation of a digital map of the city, updated to 1992 (the date when the latest aerial photographs were taken), and a GIS of the existing sewer system.

Six students received training in environmental engineering, and six in GIS. None of the participants in the group assigned to the sewerage system had previous training in environmental/sanitary engineering. Only one in the other group had experience with GIS, and one was a professional cartographer. Therefore, doing the project with untrained personnel was a challenge that would have been impossible to accomplish without a strong training component in the project.

The work proceeded with the teams in Guayaquil generating the field evaluation data for the several system components, for their analysis, evaluation, and model generation, and with the teams at UNO generating the preliminary design alternatives and the GIS. Through the training of the Ecuadorian faculty and engineers, the Foundation should be viewed as an organization working with the Republic of Ecuador in formulating and implementing measures that will have a long term affect on the pollution, and on the production of environmentally sound activities, directly benefitting the health of the population and the national economy.

Results - At the end of the ESPOL-UNO project the following results were delivered to Ecuador:

- Eight Ecuadorian engineers from the ESPOL staff were trained in several technical areas. Five have acquired an academic background and can participate in the Environmental/Water Resources Engineering training at ESPOL in Guayaquil. Another ESPOL faculty member will return to Ecuador in 1996, with an M.S. in Environmental Engineering, to join the other five in their environmental engineering training activities. The other two ESPOL staff members are now specialists in Cartography and GIS, and therefore can transfer this technology to their students at ESPOL.

- Three engineers from EMAG have been trained in Environmental Engineering at the graduate level, two of whom received additional academic and practical training on GIS.

- An IGM engineer received training in Cartography, Geodesy, and GIS.

- An updated digital map of the city of Guayaquil has been prepared showing details at the block level. Copies from it can be printed at any scale using either a PC printer or a plotter.

- A GIS of Guayaquil's existing sanitary sewer system, linked to the hydraulic analysis software, was created. The digital map mentioned above and the GIS can now be used by EMAG in the final design of the new sanitary sewer system of the city of Guayaquil.

- A computer program for the hydraulic analysis of the Guayaquil sanitary sewer system was also prepared specifically for this project. It can be used to predict the behavior of existing sewers as well as to design new lines that will be constructed in the future by EMAG.

- A conceptual design of the measures for immediate implementation to rehabilitate Guayaquil's sewerage system was delivered in January 1995.

- A technical feasibility study of the new Guayaquil sewerage system to meet the demand at the end of the design period (2025), delivered in May 1995 (La Motta [3]). It is important to mention that most of the work has been done by Ecuadorian engineers under the supervision of the UNO faculty.

- An ongoing cooperative relationship between ESPOL, EMAG, and UNO that has the ultimate goal of improving the local environmental conditions.

Summary and Conclusions

An educational approach for addressing environmental problems in a developing country has been successfully tested in Ecuador by the UNO UWMRF. This project, Proyecto Guayaquil, was initiated through an international cooperative agreement between ESPOL, a technical university in Guayaquil, Ecuador, and the UNO UWMRF, in a grant provided by the Ecuadorian Government. It included educational programs and training of Ecuadorian engineers in the fields of Environmental Engineering and GIS while developing the technical feasibility study of the Guayaquil sewerage system. With the successful completion of this project the following conclusions can be drawn:

- The educational objective, i.e., training, has clearly been accomplished. By the end of the program, Ecuador acquired eight new Ecuadorian engineers with a Master's degree in environmental engineering, two with a Master's degree in civil engineering with emphasis in cartography, geodesy and GIS, and with two specialists in GIS. Six have a complete knowledge of the Guayaquil sewerage system, and the other six, of the sewerage system GIS.

- Effective technology transfer has already occurred and will continue by virtue of the twelve project participants returning to Ecuador to work at the

institutions involved in the project. Eight participants are ESPOL staff members, and therefore will actively participate in training local engineers, and three are EMAG staff members who will work in developing solutions to the Guayaquil sanitation problems.

- Much of the project was accomplished through the direct effort of the Ecuadorian engineers themselves. This has given them a sense of self-confidence in doing this work and in looking for appropriate solutions for the Guayaquil environmental problems.

- Modern technology, including software to analyze the hydraulic performance of the sewer system and pumping stations, and a digital map of the city were specifically prepared. The software for hydraulic sewer network analysis is in Spanish and can be used in Guayaquil by EMAG engineers.

- This novel approach is much more effective than the traditional one of hiring international consulting firms, which leave the country after they finish their activities with little technology transfer.

References

1. "Remediation of Urban Environment in the Guayas Region, Ecuador," Proposal No. UWMRF TP 91-F152, *UNO Urban Waste Management and Research Foundation*, March 27, 1991.

2. La Motta, E., Editor, Technical Feasibility Study of the Sanitary Sewerage System of the City of Guayaquil, Annual Report, *Technical Report No. 94-19, Urban Waste Management and Research Center*, University of New Orleans, New Orleans, LA, June 1994.

3. La Motta, E., Editor, Technical Feasibility Study of the Guayaquil Sanitary Sewerage, Final Reports Vols. I-IX, *Technical Report No. 95-09, Urban Waste Management and Research Center*, University of New Orleans, New Orleans, LA, May 1995. (in Spanish)

4. La Motta, E. J., and Castro, F., Manual for the Technical Evaluation of Water Supply, Sewage, and Solid Wastes Projects, *Ecuadorian Development Bank, Municipal and Urban Infrastructure Program*, Quito, Ecuador, 1991.

5. La Motta, E. J., Manual for the Technical Evaluation of Environmental Assessment Studies of Urban Infrastructure Projects, *Ecuadorian Development Bank, Municipal Urban Infrastructure Program*, Quito, Ecuador, 1991.