# Water Resources Research Institute

# Annual Technical Report

# FY 2000

## Introduction

The Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) (formerly Puerto Rico Water Resources Research Institute, PRWRRI) was established in 1965 by virtue of the Water Resources Research Act of 1964. Located at the Mayagüez Campus of the University of Puerto Rico (UPRM), the PRWRERI has served the water professional community of the beautiful island of Puerto Rico for over 35 years. Being a Caribbean island, Puerto Rico exhibits unique and exciting hydroclimatic characteristics, which produce a diversified array of hydrologic responses in very short aerial extensions. These conditions provide an excellent setting for research in the tropical and Caribbean water resources field. The PRWRERI serves all higher education institutions in Puerto Rico and contribute to the solution of local and island-wide water related problems.

## Research Program

### Basic Information

| | |
|---|---|
| **Title:** | Comprehensive Approach for Hazard Mitigation in Rio Grande de Añasco |
| **Project Number:** | N-01 |
| **Start Date:** | 10/1/2000 |
| **End Date:** | 9/30/2002 |
| **Research Category:** | Engineering |
| **Focus Category:** | Floods, Water Quantity, Models |
| **Descriptors:** | Flood hazard mitigation, 2-D modeling, Hydraulics |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Jorge Rivera-Santos, Walter F Silva |

### Publication

## Problem and Research Objectives

The National Flood Insurance Program has created a repository of flood hazard data for floodplain management and flood insurance purposes. The final product is the creation of a Flood Insurance Study (FIS) which is accompanied by a Floodway Insurance Rate Map or a Floodway Map. Most of the FIS were developed using field data and historic information to calibrate a computer model to obtain flood elevations and delineate the flood prone zone. Those models were developed using the U.S. Corps of Engineers' one-dimensional computer program HEC-2. There are flood areas were no detailed study has been done. The Planning Board of Puerto Rico adopted the FIS Maps as a model for the development of the Flood Prone Area Maps used as the regulation maps for construction permit issuing supported by hydrologic/hydraulic (H&H) studies in Puerto Rico. At present, an improved version of HEC-2, namely HEC-RAS, is used as the recommended computer model for H&H studies in Puerto Rico, but it is still one-dimensional modeling.

A major limitation of the HEC-2 or HEC-RAS computer model is the assumption of one-dimensional flow, which may not represent accurately the flow and velocity distribution in the coastal areas. On the other side, all the major rivers of Puerto Rico have extremely wide floodplains near the coastal zone, therefore, the use of this model could not be fully justified in many cases. These floodplains expand from a very narrow canyon to a wide valley in an extremely short distance, which makes the assumption of one-dimensional flow very hard, if not impossible, to maintain.

The Río Grande the Añasco floodplain represents a typical case where the aforementioned situation occurs. Flood problems in the lower parts of the Río Grande de Añasco basin are serious and cover a large extend. More than seventeen (17) floods occurred in the area during the last thirty years, causing damage to residential areas; as well as, sugar cane crops, pasture lands, roads, and utility services. These floods cover reaches more than 2,000 meters wide near the coast zone and inundate several communities in the municipalities of Añasco, Rincón, Las Marías, San Sebastian, Maricao, and Mayagüez. This project proposes a detailed study to analyze the implications of using one-dimensional modeling in H&H studies as opposed to using multi-dimensional modeling, to establish procedures to conduct multi-dimensional modeling and guidelines for field engineers, and to recommend specific mitigation measures for the flood prone areas in this communities.

The specific objectives of the project are:

1. To analyze the appropriateness of using one-dimensional models for H&H studies in the Río Grande de Añasco flood zone and to suggest techniques to improve simulations for these studies within the limitations of these models.
2. To propose flood protection and mitigation measures for the major communities affected by floods from this river.
3. To produce a case study where the procedures and techniques developed could be used as a raw model for other areas in Puerto Rico and abroad.

## Methodology

A detailed study of the hydrologic and hydraulic conditions of the Río Grande de Añasco flood area will be developed. The project will use state-of-the-art hydrologic and hydraulic models, combined with state-of-the-art GIS and GPS techniques to obtain updated data. This project will complement other projects currently conducted by the Water and Environmental Resources Research Institute of the College of Engineering at UPRM, such as the "Comprehensive Plan for the Integrated Management of the Mayagüez Bay Watershed" project, which includes three mayor rivers; Río Grande de Añasco, Río Yagüez, and Río Guanajibo.

## Principal Findings and Significance

This is an ongoing project in its first year. Results are limited at this moment. Data from FEMA's hydraulic consultants were acquired and the HEC-RAS version of HEC-2 model was built. Preliminary simulation runs were performed and the model is ready for calibration. Other digital data acquired included USGS Quadrangles, aerial photographs from NOAA, soil types and land cover layers, and the USGS 30-meter DEMs. A preliminary land cover was established. Also, the flood plain boundary was digitalized and superimposed on the USGS quadrangles. This is the first step in the PGS network construction. A Field trip was conducted to examine the flood plain and identify problematic areas that will require special attention during field data collection and modeling efforts.

## Basic Information

| | |
|---|---|
| **Title:** | Cumulative and Secondary Impact Assessment Modeling Program for the Jobos Bay Esturine Research Reserve Watershed |
| **Project Number:** | N-02 |
| **Start Date:** | 4/1/2000 |
| **End Date:** | 9/30/2001 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Non Point Pollution, Models, Water Quality |
| **Descriptors:** | Pollutant transport, models, BASINS, GIS |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Jorge Rivera-Santos, Luis Olivieri |

## Publication

## Problem and Research Objectives:

The Coastal Zone Management Program (CZMP) is approximately mid-way though a 3-year effort to integrate Cumulative and Secondary Impact Assessment (CSI) into management decision making for coastal resources. This activity is funded by the National Oceanic and Atmospheric Administration (NOAA) under the section 309 program enhancement provision of the amended Coastal Zone Management Act (CZMA, 16 U.S.C. §§ 1451, *et esq.*). At the end of the 3-year period (Sept. 30, 2000) it is anticipated that the results of the work on CSI will begin to be integrated into the operational activities of the Puerto Rico's Department of Natural and Environmental Resources (DNER).

At its most basic level, successful integration would allow DNER to improve its review of federal and Commonwealth permit applications, zoning changes and other development actions, based on the use of measurable indices for assessing impacts. Currently, DNER does not use any quantitative measures for determining the extent of development impacts on either coastal habitats or coastal water quality. Individual project and permit reviews are largely based on conformity to regulatory provisions or guidelines, and the professional judgement of the reviewer.

While reliance on professional judgement is an essential component in development decision making, it is likely that, at some point, professional judgements are going to be challenged in legal proceedings. This is particularly true if such judgements are not supported by objective measures linking development activities to the measurable effects those activities have on coastal water quality or on protected ecosystems or habitats.

A further weakness in current practice is the project-by-project review of development impacts. There is no procedure for recording the cumulative effects of numerous, small, or even large-scale developments, on coastal and marine resources over an extended period of time. Furthermore, in the absence of consistently recorded monitoring data, the environmental impacts of development actions often remain undetected until significant damage has occurred.

In recognition of these shortcomings, DNER, the Puerto Rico Planning Board (PRPB), the Regulations and Permits Administration (RPA), and the Environmental Quality Board (EQB) entered into a MOU to develop a common approach to CSI, with DNER assuming lead agency responsibility for developing the methodology. Accordingly, in 1997 the CZMP selected Cumulative and Secondary Impacts as a priority component of the CZMA Sec. 309 Program Strategy.

Two approaches are being tried simultaneously in the work on CSI.

1. The first is a qualitative/descriptive approach for which a methodology has been developed and presented to various units within DNER.

2. The second approach seeks to design and implement quantitative techniques, using computer modeling, in combination with GIS.

In all probability, a combination of the two approaches will prove to be needed. The first relies heavily on the use of professional judgement, which will certainly influence model development. The second seeks to use objective, verifiable measures to assess impacts.

Development of quantitative techniques for assessing impacts represents a complex challenge requiring interdisciplinary skills in ecology, the biological sciences, GIS, computer programming and modeling. This range of skills is available within DNER and JBNERR staff, and the Puerto Rico Water Resources and Environmental Research Institute (WRERI). Technical support is also available from the federal Environmental Protection Agency (EPA).

With financial resources provided through the Sec. 309 program of the CZMA, supplemented by funds from next year's JBNERR budget, a coordinated team effort has been launched to develop computerized simulation models and assessment techniques for assessing the environmental impacts of land-based activities for the Jobos Bay watershed.

An initial step in the process will be a collaborative effort to adapt various existing models, beginning with EPA's Better Assessment Science Integrating Point and Nonpoint Source (BASINS) System, to the specific issues and conditions that exist within the Jobos Bay watershed. Although funds are currently programmed only through September 2000, it is anticipated that the design and implementation of management models will proceed incrementally, and will extend over a period of years beyond FY '99-00.

Overall Objectives of the Modeling Effort are:

**A. Improve Management Decision-Making**

The principal objective of the modeling effort is to provide decision-makers with the technical tools for determining the likely effects of development activities on environmental and natural resources. The south coast, including the Jobos Bay Watershed, is being subjected to increasing growth pressures, principally from residential development and large-scale tourism projects. By developing computer simulation models and quantitative assessment techniques, decision-makers will be provided with objective measures of the probable impacts such development will have on both coastal habitats and coastal water quality.

The resultant objective of the work effort will be to design and/or adapt models that can be used for…

1. Providing information on the mechanism of pollutant transport (point and non-point sources) as a result of discrete development activities and/or agricultural practices, occurring within the Jobos Bay watershed that could be used to assess the impacts on the JBNERR mangrove ecosystem.

2. Determining possible effects of pollutant discharges on waters of the Jobos estuary and other components of the habitat.

**B. Staff Training**

It is essential that staff members at DNER and JBNERR receive sufficient training in modeling and simulation techniques so as to function as effective partners with UPR's WRERI in conducting the work and future maintenance and use of the system.

An objective of the first year's collaborative effort with UPR's WRERI will be to initiate training in modeling and related activities for DNER personnel. This will include taking maximum advantage of the training that will be offered by US EPA.

**C. Networking**

DNER, EQB, RPA, and the Planning Board have a MOU that designates DNER as lead agency for developing a CSI methodology. Since EQB is committed to adapting the BASINS System to certain critical watersheds in Puerto Rico, there is a particular urgency to establishing an ongoing partnership with EQB in both the training and modeling work.

**D. Support to the SPA Process**

A major objective of the FY '99-00 effort will be to support the work of the SPA Committee. Conversely, the key Commonwealth and Federal planning and permitting agencies comprising this Committee can provide both policy guidance and technical inputs to the development of the watershed modeling work. The Committee is also well positioned to sponsor stakeholder meetings relative to obtaining consensus on habitat and water quality issues and priorities. Decisions on stakeholder participation, beyond that of the SPA participants, will be determined by the Committee.

The programmatic objectives for FY '99-00 will focus on developing/adapting computerized simulation models that demonstrate cause and effect relationships within the watershed between:

- Specific land-based activities (i.e. agricultural practices) and resultant impacts on mangrove wetlands in the JBNERR;
- Specific point source discharges (i.e. untreated sewage) affecting water quality in Jobos Bay.

The model, or models, will simulate the mechanism of pollutant generation and transport due to land use changes, land treatment (land grading/cut and fill) and other man activities within the Jobos Bay watershed. This modeling will produce the data necessary to determine pollutant loads and their effect on the quality of the waters of JBNERR and its habitat.

## Methodology:

### A. Establish the Range of Indicators to be Used in the Simulation Models

Initially, the key indicators to be used for determining hazardous conditions for habitat (mangroves) could be salinity and sediment transport. However, appropriate indicators will be established after our specialist conducts appropriate assessment of the habitat.

The initial indicators to be used for determining impacts on water quality will be sediments and nutrients. Of course, the final indicators depend on the availability of collected data.

Consensus on the full range and priority of indicators to be used has to be obtained following initial model development. It is possible that additional indicators may be incorporated into the modeling process during FY '99-00, depending on information availability, technical (modeling) capabilities, and cost.

### B. Test the Feasibility of Applying the EPA’s "Better Assessment Science Integrating Point and Nonpoint Sources" (BASINS) System to the Jobos Bay Watershed

BASINS was developed by EPA's Office of Water. It is a multi-purpose environmental analysis system, interfacing with the Arc View Geographic Information System, that integrates a wide range of data on water quality and quantity, land uses, point and nonpoint source loading, etc.

Project work will initially focus on use of the BASINS system. But the BASINS system can, and most likely will, have to be supplemented by various watersheds loading, receiving water, and ecological models. Numerous of these models are available from government agencies and private sources.

An advantage in starting with the BASINS system is that it can readily incorporate other models, as needed, to address deficiencies or gaps in the BASINS system. BASINS also has the advantage of being supported by EPA sponsored training. Continual updates are available on the web.

The WRERI will prepare the databases that BASINS needs to operate. Data, such as Digital Elevation Maps, soil types, land coverage, and others, will be managed using ArcInfo. The data include meteorological information as well as physical characteristics of the watershed.

**C. Establish a Monitoring Program**

Depending upon the indicators selected, a systematic monitoring program needs to be established. The monitoring program can build upon the work now being done through the Reserve's on going research and monitoring program. It might also be integrated with the monitoring requirements stipulated in the Consent Order between the Land Authority and EPA. Currently, JBNERR is being collecting data on the following parameters.

Well, surface, and interstitial water sample:

| | | |
|---|---|---|
| Nitrate | Salinity | Fecal Coliforms |
| Nitrite | Temperature | Total Coliforms |
| Oxygen Demand | Dissolved solids | COD |
| Chloride | Suspended solids | BOD |
| pH | Total solids | Conductivity |
| Sulfate | Hardness | Alkalinity |

Metals:

| | | |
|---|---|---|
| Zinc | Cadmio | Iron |
| Copper | Lead | Chromium |
| Cobalt | Manganese | Magnesium |

| | | |
|---|---|---|
| Sodium | Calcium | Potassium |
| Mercury | Silica | |

Pesticides:

| | | |
|---|---|---|
| Alaclor | Atrazine | Porphyrifos |

In addition, plankton chlorophyll and phitoplankton are measured in the bay waters. Other parameters measured in these waters are temperature, salinity, dissolved oxygen, turbidity, pH, and water depth.

**D. GIS Coordination**

The integrating framework for BASINS is a Geographic Information System (GIS). As noted in the BASINS Handbook: "The simulation models are integrated into the GIS environment through a dynamic link in which the data required to build the input files are generated in the Arc View environment and then passed directly to the models. The models run in a Windows environment. The results of the simulation models can also be displayed visually and can be used to perform further analysis and interpretation."

JBNERR, DNER, and the WRERI all have GIS capabilities. An operational objective of the work will be to ensure coordination in GIS activities, related to the modeling effort, between these three centers, and to provide for the training of pertinent personnel.

WRERI personnel will be in charge of the following.

a. Coordination of the GIS tasks of the project.

b. Assistance in the identification of the sources of data.

c. Assistance in the collection of these data and the transformation of the data into the BASINS file format.

d. Work in the development of data visualization as ArcView projects and hardcopy form.

e. Assistance in the training of personnel from the Puerto Rico Department of Natural and Environmental Resources and Jobos Bay National Estuarine Research Reserve in the use of the GIS requirements of BASINS.

## Principal Findings and Significance:

This is an ongoing project for which deliverables are not yet completed. The monitoring plan was submitted for review and we are still waiting for feedback from the DNER. The modeling effort is still ongoing and should be completed by end of September, 2001.

The modeling effort included the adaptation of EPA's BASINS the JBNERR's watershed. This task involved the creation of the required databases, which, for Puerto Rico, did not exist. This will allow future modeling effort for the determination of non-point pollutant sources and its propagation through the channel network of the watershed. With this tool, JBNERR's personnel will be able to implement its management plan and to assess conservation and recovery measures, which are part of it.

## Basic Information

| | |
|---|---|
| **Title:** | Development of Novel Dual-Function Media Matrix forProtecting Water Resources from Noxious Organic Wastes |
| **Project Number:** | B-01 |
| **Start Date:** | 3/1/2000 |
| **End Date:** | 2/28/2001 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Treatment, Water Quality, Methods |
| **Descriptors:** | Water Treatment, Oil and Grease, Infiltration |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Moses N. Bogere, Narinder K. Mehta |

## Publication


1. Meléndez-Colón, Daneira, 2001, Development of Novel Dual-Function Media for Treatment and Separation of Oil & Grease from Tuna Wastewater, MS Dissertation, Department of Civil Engineering, College of Engineering, University of Puerto Rico, Mayaguez, Puerto Rico
2. Meléndez-Colón, Daneira, Narinder K. Mehta, and Moses N. Bogere, 2001, Effective Novel Dual-Function Media for Separation and Treatment of Wastewaters Containing Oils & Grease, in Sixth Caribbean Islands Water Resources Congress, edited by Walter Silva, Puerto Rico Water Resources and Environmental Research Institute, Mayaguez, Puerto Rico, CD version only.

## Problem and Research Objectives:

The dual-functionality property of combinations of soil, sand, gravel and natural adsorbent is utilized in natural media to protect environmental resources such as groundwater and arable land from wastes injected in soils, landfills, caves and depleted wells/aquifers. Wastes are immobilized within the media by adsorption, absorption and encapsulation, and under favorable conditions immobilized wastes are biodegraded in a finite time. However, immobilization and biodegradation in natural media are not optimized to sustain continual injection of wastes without pollution. This is mainly because the important media properties are bound to fail under certain environmental conditions: leakage of the media upon contact with heavy rainfall infiltration, flooding, and rising of the water table. Furthermore, in-situ biodegradation fails also to take place within a finite time if there are insufficient microbes to engineer contaminant species reaction pathways. Several studies have validated the fact that soil acts as an immobilizing agent for various components found in wastes. It is also established that many undesirable components of injectable wastes especially sludge consisting of mainly oils & grease are not easily biodegraded as fast compared to other constituent components. First of all, it is difficult to separate large amounts of oils & grease from wastewater. The problem tackled in this investigation was to develop novel cost-effective dual-function filter media for separation, immobilization and treatment of wastewaters containing high concentrations of oils & grease and odorous organic particulates. Tackling this problem should prevent contamination caused by injectable noxious and organic wastes found in sludge containing mainly oils & grease.

The objective of this work was to develop and to determine the effectiveness of novel dual-function media matrix for the immobilization of odorous wastewater mixtures containing large quantities of oils and grease. The media and immobilized wastes were used to study and to optimize in-situ biodegradation. The wastewater used in this study contains high concentrations of oils and grease, in the *500* to *10000 ppm* range, and suspended solids. These wastewaters pose unique challenges since they contain high concentrations of oils, grease and odorous biodegradable solids. The specific research objectives addressed in this study included: (i) conducting filtration tests using novel (dual-function) media matrix to separate and immobilize oils & grease; (ii) in-situ biodegradation tests on media matrix containing immobilized oils & grease and organic particulates. The other objectives (which are part of an on-going study) are to study washing and biofiltration of the media with immobilized wastes and optimization of dual-functionality properties. The central focus was to develop effective and economical novel dual-function media to separate oils & grease from wastewater and to treat immobilized wastes by increasing in-situ biodegradation rates through inoculation and biofiltration.

## Methodology:

The investigation was divided into three major parts: solid-liquid separation using dual-function filters; immobilization and washing tests; and biodegradation and biofiltration tests. The methodology and procedures are discussed below.

***Solid-liquid separation using dual-function filters:*** A high-efficiency depth filter was modified to function as a dual-function filter media by inserting immobilizing media matrix into the filter chamber. As demonstrated (from on-going work) dual-function filters are very effective for separating oils & grease and particulates from wastewater.

The mixtures handled consist of combinations of wastewater, oily phase and odorous organic particulates. The first objective was to separate the dispersed oily phase and particulates from the multicomponent wastewater mixture. Several materials (walnut, bagassee, corn, sand, and adsorbents) and their combinations were tried with the purpose to develop enhanced dual-function media matrix. Enhanced media consists of transport layers (membrane-like septum for high-pressure filtration) and a mass transfer zone (dual-function media matrix). The filtration characteristics and mass transfer rates of the enhanced media combination were then studied.

The study focused on understanding the complex fluid-solid interactions within the transport layers zone and in the media matrix (mass transfer) zone, and performance characteristics under different operating constraints. The penetration depth of oily phase and its effects on septum clogging characteristics, two-phase flow, and particulates and oily phase retention rates, immobilization of wastes and the effect of particle size in the depth (mass transfer) zone were to be established.

The generic experimental setups essentially consist of the components shown in Figure 1. The setup consists of a multiphase-multicomponent mixture feed tank, dual function filter, filtrate tank, incinerator, air heater and blower. The separation step consists of the feed tank, separator (shown in Figures 2 and 3) and filtrate tank while, the regeneration step consists of a blower, air heater, incinerator and vent. *The regeneration part of the experimentation was not part of this investigation*. In addition to the bag (Figure 2) and cartridge filters (Figure 3) were to be used also in this study during the second stage of the investigation, and a deep bed filter shown in Figure 4 was used to conduct washing tests. The main focus of the experimentation on the separator was to determine its separation efficiency using the high efficiency filter (with dual-function media).

Generally, this part of the study included the following itemized tasks:

1. Sample preparation. Laboratory samples of multiphase mixture samples composed of organic solid, oil, water, clay, polymer and sand were prepared. The candidate samples from industry were stored in sealed drums or containers. The samples were added to the feed tank only when they were needed (*the samples need special handling and disposal*).

2. Dual-function filter media preparation and loading. This involved

    - Particle size analysis of media material (a combination of clay, soil, sand, gravel, anthracite, a mixture of polymeric adsorbent and combinations of biosorbents: coffee husks, bagasse and walnut).

    - Immobilization studies dealt with selection of adsorbent and biosorbents based on oils/tar removal efficiency. The removal efficiency of each media has been determined however, the exact combination of media and biosorbent(s) required to immobilize wastes should be established experimentally based on on-going studies. Separate tests in batch mode were conducted to determine the most suitable combination adsorbent for a given oils and grease content in wastewater. These tests were quite cumbersome because raw wastewater samples tested so far contain 800 to 4000 mg/L oils & grease. Saturation tests were conducted on several media combinations in batch mode. Additional tests are planned on media containing a combination of activated carbon and natural zeolites (these are intended to remove odorous components in wastewater but not oils & grease).

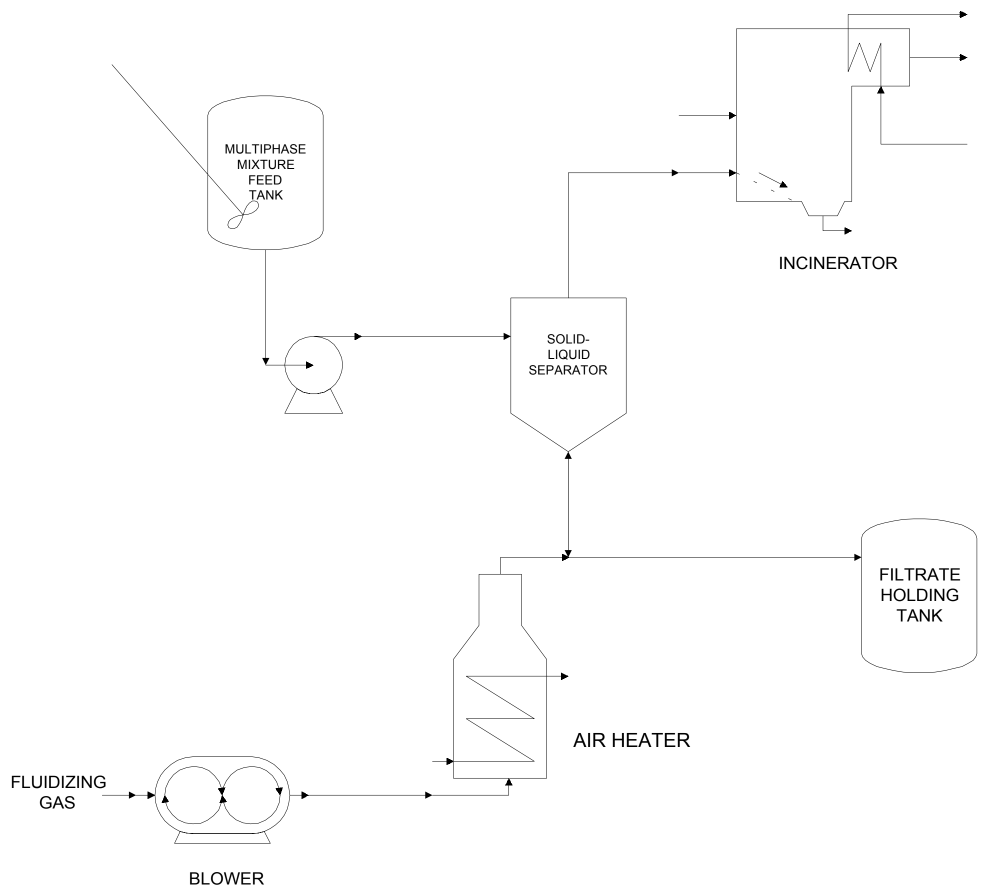



**Figure 1 Major components of the experimental setup**

3. Solid-liquid separation experiments on test rig. These tests were carried out first on the high-efficiency dual function bag filter, but they will also be conducted on the cartridge filter. The first test rig type has been setup while the second setup will use the same equipment except that a cartridge will be inserted into the filter chamber

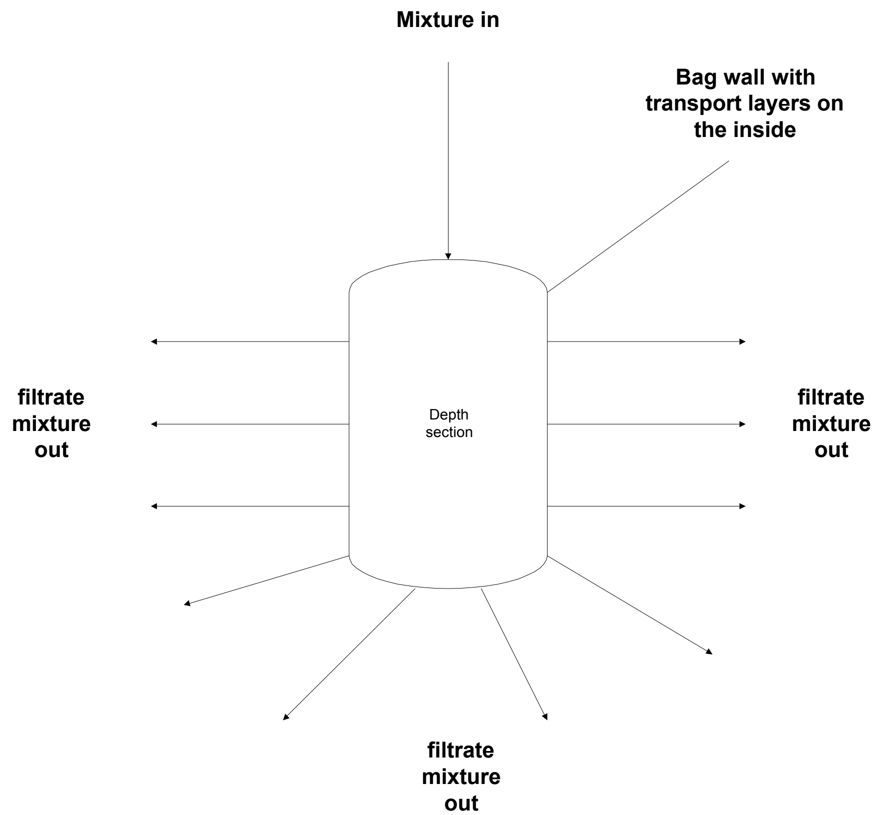



**Figure 2 Filter bag**

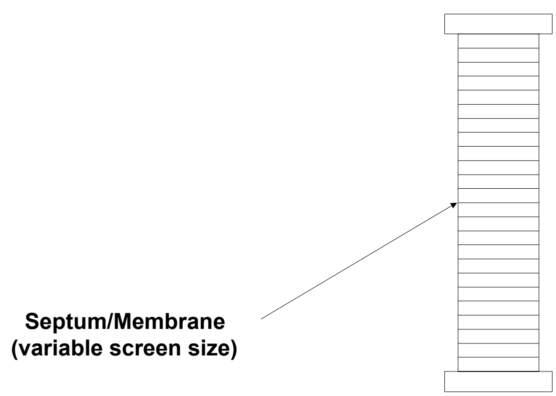



**Figure 3 Filter cartridge**

instead of the bag (this however involves reversing the flow). The oil/tar and solids recovery efficiency was determined for various dual-function filter media.

The separator is a high efficiency (batch mode) filter shell into which the filter bags or cartridge filters are inserted. The filter bag type is constructed of polyethylene materials with different micron size selection. The bags include additional transport layers attached to the bag. The media to trap the oils and odorous substances was inserted into the bag. The particulate solids and immobilized oils retained in the bags are to be used in further studies on washing, immobilization and biofiltration.

***Immobilization, washing, biodegradation and biofiltration tests:*** The retained solids, sludge and dual-function media in the filter bags were conditioned for further tests. Additional materials were added to simulate injection site conditions but these studies are to the on-going study. It is planned that the resulting material (solid matrix plus waste) will be added to the depth bed (as shown in Figure 4) and washing tests will be conducted. The objective of these tests is to determine the ability of the solid matrix to retain and immobilize oily wastes in light of extenuating conditions. The solid matrix will be optimized through further tests to maximize waste retention in a finite time. Other filter bag material will be used in biofiltration/biodegradation tests.

Oil-eating microbes, the Biotech 2000 Formula IV, have been used in this investigation. These were added to raw wastewater samples to determine their effectiveness and to establish the right amount to be added.

Further tests will be conducted to determine the characteristics of injection site material (with the waste): its waste retention rates during washing and biodegradation rates (also during washing).

## Principal Findings and Significance:

Over the previous nine months the PIs have conducted studies related to Phase I of the investigation. The data generated so far has shown that high efficiency depth filters are capable of separating oils/grease, odorous biodegradable solids and other solids from tuna wastewater. Over a four-month period the average daily concentration of oils and grease was found to be *2000 ppm* and 2800 *mg/L* of total suspended solids (TSS). However, under test conditions, experiments have shown that oils & grease content in raw samples varied from 800 to 3000 mg/L. Therefore, in order to evaluate the performance of the media, percentage removal of each filtration test was used as a basis for evaluating data. On average batch saturation tests and test rig experiments have established that the materials remove about 60 to 90% of oils & grease from raw wastewater, walnut producing the best results (see Table 1). The combination of them will certainly remove more oils & grease. It has been established that any conventional separation method usually fails in these circumstances (due to rapid fouling of the media). The results show that dual-functionality of the media once optimized is capable of immobilizing and biodegrading oily wastes/sludge. The key to fast and in-situ biodegradation is to embed a priori oil eating microbes and nutrients into the matrix. Generally this procedure should reduce the amount of sludge that is generated at the wastewater treatment site.

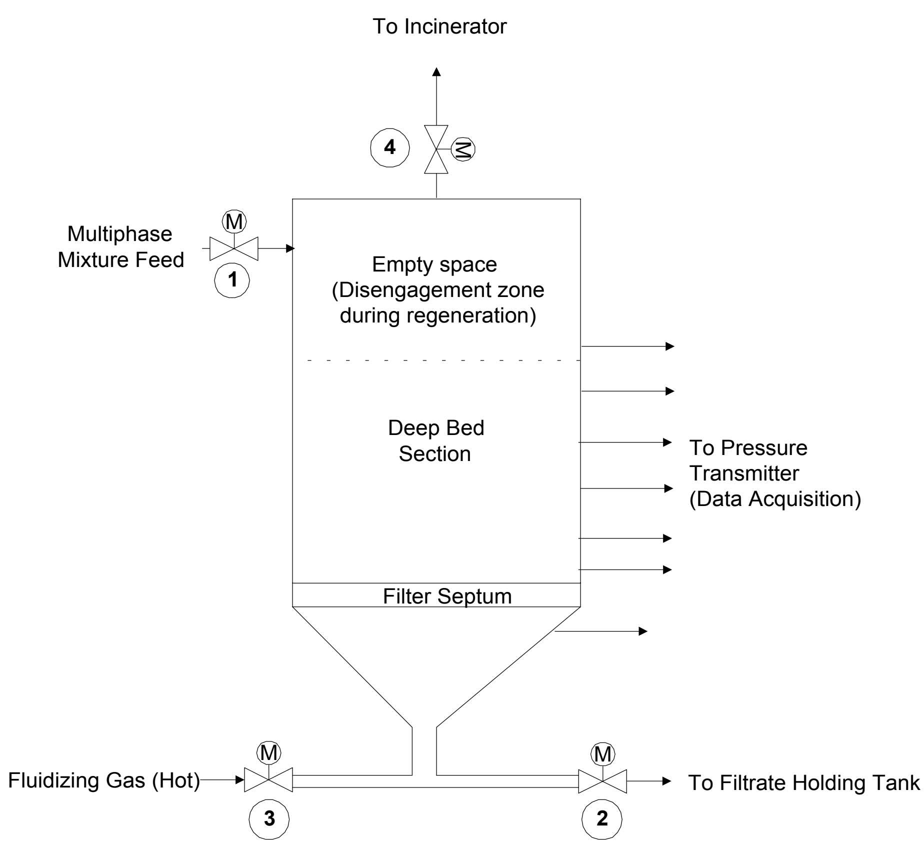



**Figure 4 Major components and instrumentation of the solid-liquid separator**

The major candidates for dual-function media are walnut shells (bead-sized particles), bagasse and high-efficiency filter media (from Ronningen-Petter filter company). Additional tests are being conducted to determine the right media combination.

**Table 1 Efficiency of oil & grease removal from wastewater using various media**

| |
|---|
| Walnut: bead-sized – 90% oils & grease recovery |
| Bagasse: 60-70% oils & grease recovery |
| Corn (to be re-used in animal feeds) - ? (no predictable results) |
| Sand/gravel - 60% oils & grease recovery |
| Bag filter (RP 527A: 9-13 micron size): 70-85% oils & grease recovery |
| Dual-function media (bag with media insert): 85 - 95% oils & grease recovery |
| Raw wastewater plus (5mg) oil-eating microbes : about 50% oils & grease biodegraded |

## Basic Information

| | |
|---|---|
| **Title:** | Comprehensive Integrated Management Plan for the Mayaguez Bay Watershed: Stage 3 |
| **Project Number:** | N-05 |
| **Start Date:** | 10/1/2000 |
| **End Date:** | 9/30/2001 |
| **Research Category:** | Engineering |
| **Focus Category:** | Management and Planning, Conservation, Education |
| **Descriptors:** | Watershed Management, Stakeholders, Restoration, Conservation |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Jorge Rivera-Santos, Jorge I. Velez |

## Publication

## Problem and Research Objectives

The Mayaguez Bay watershed is an important natural resource for many diverse groups such as private industry, local merchants, fishermen, surrounding communities, and public citizens's groups including civic and environmental groups. Noted in the not too distant past for its beauty, it has lately fallen upon hard times; a few years ago a newspaper account listed it as one of the four worst contaminated coastal areas in Puerto Rico. Several factors have led to this decline: increased population, urbanization, agricultural activity and industrialization. Several attempts have been made both to identify the causes and to find solutions. But these attempts have not improved the condition of the watershed. One of the reasons for this failure--cited by the authors of the proposal mentioned above--is the "lack of integration and coordination of efforts among the interested parties (stakeholders)." A master plan, well conceived and implemented, is needed to successfully restore, conserve, protect, and manage the resources of the Mayagüez Bay watershed.

To this end, the Environmental and Water Resources Research Institute (hereafter EWRRI) wrote and submitted a proposal for the development of a comprehensive integrated watershed management plan for the Mayagüez Bay. The project was envisioned as a series of stages where subsequent stages would build upon the results of previous stages. Stage one consisted of two phases, namely, “Investigation of Previous Works and Existing Information” and “Organization of the Stakeholder Forum.” Both phases were performed simultaneously. As a result of this first stage, the University of Puerto Rico at Mayagüez, through its Environmental and Water Resources Research Institute, has developed a partnership between the academia, researchers, government, and interested private groups to develop and implement a comprehensive integrated management plan for the Mayagüez Bay watershed. This partnership integrates an interdisciplinary group of professionals such as:

♣ Civil and environmental engineers, biologists, chemists, marine scientists, environmental scientists, planners, economists, and sociologists, who are well acquainted with the pollution problem of the region and the latest best available technology that could be applied;

- ♣ Government decision makers and administrators; and
- ♣ Interested parties such as industries, merchants, fishermen, community, and civic and environmental groups.

The project will provide:

1. The development of a comprehensive integrated management plan for the Mayagüez Bay watershed that permits the restoration, conservation and protection of the quantity and quality of its natural resources, and that establishes a balance within the system uses and its ecological integrity;
2. The development of an organizational structure that ensures the participation of the stakeholders, and integrates and coordinates the administration and management of the expected efforts toward the solution of the pollution problem;
3. The development of strategies to restore, protect, and manage all pollutant sources within the watershed; and
4. The development of an implementation plan that guarantees that the developed plans and strategies will perform as intended and expected.

Success in conducting this project will lead to improved quality of life for all habitants within the Bay and the watershed, as well as for surrounding areas. The establishment of such a plan will allow the best utilization of the resources in a way that ensures the integrity of the ecosystem. Integration and communication between the different stakeholders will be greatly enhanced. The outcomes of the effort will include:

1. An integrated conservation and management plan for the whole Mayagüez Bay watershed;
2. A GIS database/inventory of all pollutant sources and strategies for their restoration, protection, and management;

3. A program within the Environmental and Water Resources Research Institute to coordinate and manage the efforts; and
4. An implementation plan.

### *STAGE I*

Phase I of Stage I of the proposed Comprehensive Integrated Management Plan (hereafter CIMP) brings about the "integration and communication" of the stakeholders in the context of the Mayaguez Bay watershed. To help achieve this, the authors are employing the Vital Issues Process developed by Sandia National Laboratories. The Vital Issues Process (hereafter VIP) consists of day-long panels. Each panel is led by a facilitator whose function is to channel the discussion through certain prescribed stages; a morning qualitative session (consisting of an open, round table discussion between stakeholders) and an afternoon, quantitative session (consisting of comparing, ranking and prioritizing the results of the morning discussion using a "net benefit maximization method"). A recorder or rapporteur attends each panel. He prepared a draft report for each panel that captured the ebb and flow of the discussion. The draft then was distributed to the panelists for comments and suggestions.

The key participants in the VIP are the panelists themselves. Each panel is formed of individuals carefully chosen for their expertise relative to different stakeholder groups. The stakeholder groups represented fall roughly into four categories: *academia* (participants taken from university and secondary faculty as well as other participants broadly involved in education and research issues), *public citizens's groups* (consumer groups, environmental groups, or other organizations formed by individuals concerned with a public problem or issue), *private industry* (individuals representing for-profit corporations), and *government* (individuals representing key government agencies). The participants in the subsequent panels were, for the most part, not be the same individuals; yet they were chosen in a similar manner.

The three panels themselves are related in the following manner. The first panel : (1) crafted an objective statement which summarized the goals to guide it and subsequent panels in their reflection on vital issues; (2) used the objective statement, along with certain "metacriteria", to generate and refine a list of issue selection criteria to help the second panel choose issues to serve as the focus of further proposals solicited to help carry out the CIMP; (3) compared, ranked, and prioritized the proposal selection criteria by means of a quantative, net benefit maximization method.

The second panel built upon the first; took the objective statement plus the issue selection criteria and rankings and used these to identify, clarify, refine, and synthesize the vital issues to be addressed in further proposals. Then a third identified the content of these issue-specific proposals. For example, it analyzed the vital issues identified by Panel II and then discussed various activities which would respond to these vital issues; for example, they identified information needs raised by the proposal issues and specified information delivery systems to place this information in the hands of decision makers. The result was a process that facilitates stakeholder participation and helps ensure that proposals generated in relation to the CIMP will reflect genuine stakeholder concerns.

The objectives of this Second Stage are:

1. To develop the Strategic and Operational Plan for the Conservation and Management of the Rio Grande de Añasco
2. To disseminate and implement the organizational structure for the CIMP
3. To disseminate the institutionalization of the Stakeholders Forum and its objectives
4. To develop a prototype for an evaluation process for the Request for Proposals for the research program

## METHODOLOGY

It was proposed to use of the Vital Issues Process that we successfully used in Stage I (See Figure 1). The following activities were developed:

1. Four panels or workshops with the Stakeholders Forum
2. Four meetings with the Technical Committee to design the evaluation process for the RFP

3. Dissemination of the process through the Internet and brochures

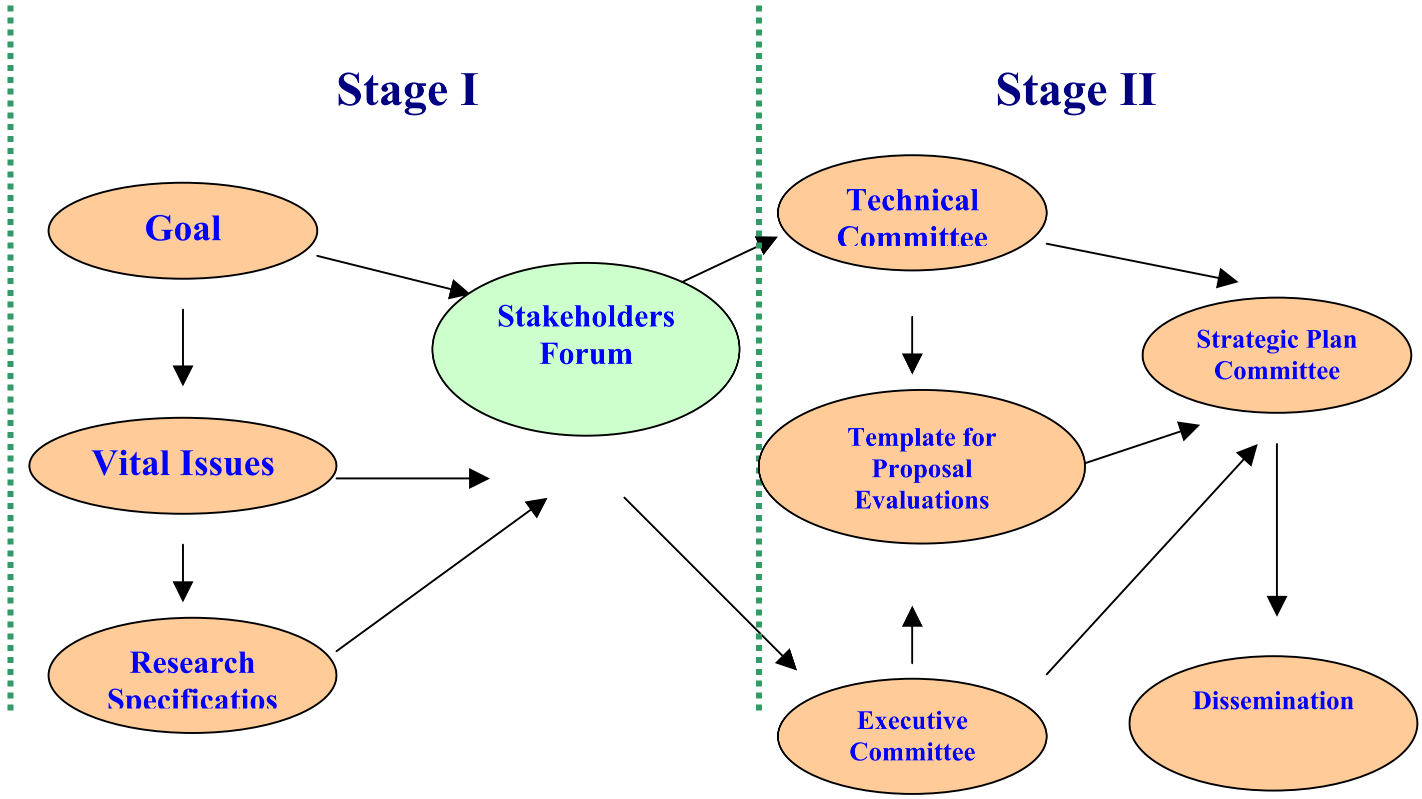



**Figure 1. Relationship between Stage I and Stage II**

## Principal Findings and Significance

AT the end of the second year if this ongoing project, two more committees were formed. The Technical Advisory Committee (TAC), which has the responsibility of advise the Stakeholder Forum and the newly formed Administrative Advisory Committee, in all technical aspects of the project. This committee is in charge of the technical evaluation of all research proposals submitted to the project. The composition of the committee is of about 15 members and change periodically according to the necessity of the project.

The second organized group was the Administrative Advisory Committee (AAC). This committee is responsible for providing general administrative guidance to the Stakeholder Forum. It is composed of government officials and private individuals with vast experience in water resources project administration. They are in charge of identifying financial sources for the project.

A call for pre-proposals was pulled out to which 11 submissions were received. The TAC evaluated these pre-proposals and selected 7 for full proposal submission. The evaluation criteria were established by the Stakeholder Forum. The TAC identified peer reviewer for the seven proposals and received their comments and suggestions. Then, a final meeting of the TAC resulted in the ordering of the proposals by the number of points received during the evaluation process.

Meanwhile, the AAC identified a source of funds in the Puerto Rico Aqueduct and Sewer Authority (PRASA). These funds were set aside by PRASA to conduct research in the area of Mayagüez Bay. A first installment of $125,000 was received in the Institute and was dedicated entirely to the project. In this manner, the first three proposal were recommended for funding and are supposed to begin in August 1, 2001.

## Basic Information

| | |
|---|---|
| **Title:** | Dynamic Simulation of Water Distribution System with Instantaneous Water Demands |
| **Project Number:** | B-02 |
| **Start Date:** | 3/1/2000 |
| **End Date:** | 2/28/2001 |
| **Research Category:** | Engineering |
| **Focus Category:** | Water Use, Models, Water Supply |
| **Descriptors:** | Water use, Water Demand, Statistical simulation, Water distribution systems |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Walter F Silva |

## Publication

**Problem and Research Objectives:**

This investigation presents a methodology to model residential water consumption by using a micro-scale simulation algorithm. The new algorithm combines an unsteady flow model with an instantaneous demand model. The instantaneous demand model was constructed from probability distributions for the simulation of time of aperture and the duration of valve openings inside a house. Several households were represented on an experimental setup to verify the ability of the model to respond to the dynamic nature of the instantaneous water use. The input data for the model are pressure measurements at the upstream end of the water distribution pipe and, the discharge at the beginning of the simulation.

This investigation presents a comparison between measured and computed results obtained with the new model. An excellent prediction of the time-dependent discharge along the distribution pipe was obtained for different demand scenarios; therefore, the model is capable of responding to the random components of the water use. The new methodology has potential application in neighborhoods with relatively homogeneous consumption patterns where a representative set of statistical parameters for the probabilistic model can be derived.

**Methodology:**

*Hydraulic Model*

The equations used in the mathematical model to simulate unsteady flow correspond to the continuity and dynamic equation. The partial differential equations, that describe the unsteady flow of a slightly compressible fluid, become ordinary differential equations after transformation by the Method of the Characteristics. The final equations for a pipe segment are (Chaudhry, 1987):

$$\frac{dQ}{dt} + \frac{gA}{a}\frac{dH}{dt} + \frac{f}{2\mathrm{DA}}\mathrm{Q}|\mathrm{Q}| = 0 \qquad (1)$$

$$\frac{dQ}{dt} - \frac{gA}{a}\frac{dH}{dt} + \frac{f}{2\mathrm{DA}}\mathrm{Q}|\mathrm{Q}| = 0 \qquad (2)$$

where: $Q$ is the discharge, $t$ is the time, $g$ is the acceleration of gravity, $A$ is the area of the pipe, $a$ is the wave velocity, $H$ is the piezometric head, $f$ is the Darcy-Weisbach friction factor and $D$ is pipe internal diameter. These equations are valid along the characteristic lines (Figure 1) and their solution provides the pressure head and the flow at the intersection of the characteristic lines. Additional information at the boundaries is necessary for a complete solution.

Three boundary conditions were used, namely: 1) continuous pressure head values measured during the experiment at the upstream end, 2) a sequence of on-off constant discharges, representing household connections and generated from statistical simulations, were used along the distribution line and, 3) an orifice equation governed the downstream discharge. Figure 2 presents a schematic of the experimental setup.

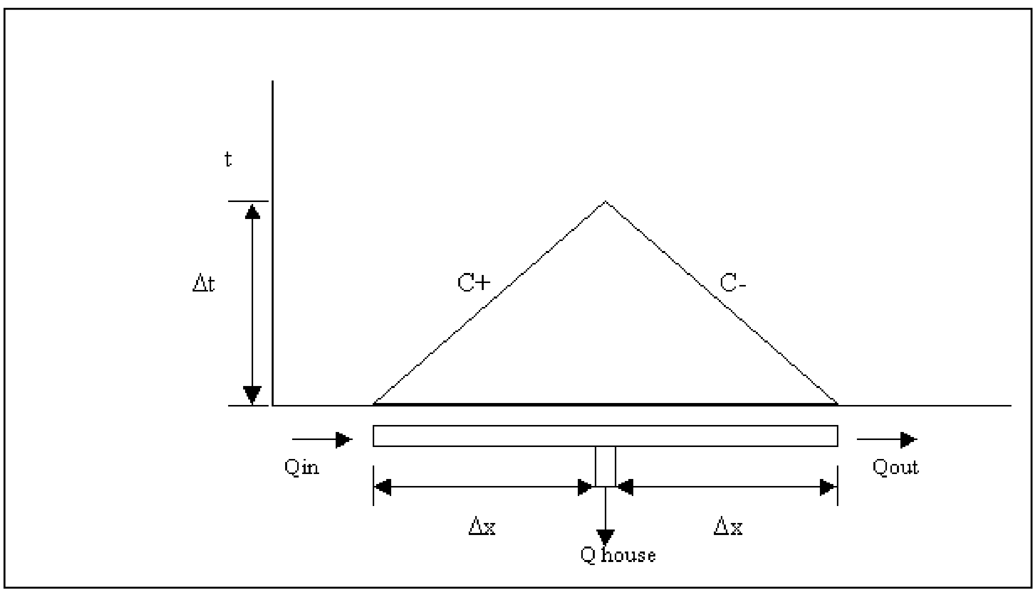



Figure 1. Residential connection and characteristic lines

The continuity equation at each household connection is given by:

$$Q_{in} - Q_{out} - Q_{house} = 0 \quad (3)$$

where $Q_{in}$ is the flow upstream of a house, $Q_{out}$ is the downstream flow and, $Q_{house}$ is the household demand.

If the pressure head and discharge at the beginning of the simulation are known, and the statistical model provides the sequence of inflow to the house ($Q_{house}$) then equations 1, 2 and 3 can be solved for $Q_{in}$, $Q_{out}$ ,and, the pressure head ($H$) at the next time step. The calculations are repeated for the next time interval until the simulation time is completed. More details on the solution procedure can be found in Silva-Araya and Durán (1998).

*Discrete Demand Model*

The residential area is assumed to be compounded of many houses with similar consumption patterns. The operation of household devices inside the house is represented by a series of events consisting of opening and the closures of valves. The consumption patterns in a residence are characterized by three variables: intensity, duration and frequency. As a first approximation of the model, the intensity was assumed constant. This means that the quantity of water per unit of time that enters a house remains constant during the time of use, independently of how many faucets are open in the house. The frequency refers to the interval of time between two consecutives demands. The duration is the interval of time that a faucet remains open.

Statistical distributions are used to model events with random components. Certain statistical distributions could therefore, be adjusted to simulate such events (Banks and Carlson, 1995). Water demand at each household could be treated as a random variable; consequently, random generation techniques where used to simulate the instantaneous water use. The discrete model generated different sequences of openings and closures of valves in each household. The time between openings was simulated using the Exponential distribution. Mean duration times of three to six minutes where chosen to test the hydraulic model under laboratory conditions. The equation for this model is (Banks and Carson, 1995):

$$T = -\frac{1}{\lambda}\log(R) \qquad (4)$$

where λ is the number of times that a valve is opened per unit time, *T* is the time between two consecutive openings of the same valve, and *R* is a random number between 0 and 1. It is assumed that the simulation of the opening of one valve is independent of the other valves; however, the model could be adapted to simulate the operation of more than one valve inside the house during the same time interval (Collazos, 1999). The duration of the valve openings was simulated using the Exponential , the Weibull and the Log- Normal distributions. The equations are (Banks and Carson, 1995)

$$D_u = -\frac{1}{\lambda}\log(R) \qquad (5)$$

$$D_u = \alpha\left[-\ln(1-R)\right]^{1/\beta} \qquad (6)$$

$$Du = e^z \log(R) \qquad (7)$$

where,

$$z = \mu + \sigma\sqrt{(-2Ln(R)}\cos(2\Pi R)) \qquad (8)$$

For the Exponential, the Weibull and the Log-Normal distributions respectively. $D_u$ the duration of the opening, α and β are the parameters of the Weibull distribution, *R* is a random number between 0 and 1, μ and σ are parameters of the Log-Normal distribution. Equations 4, 5, 6 and 7 were used to generate different sequences with different times of openings and closures of faucets to study the variability in the consumed volume of water.

**Principal Findings and Significance:**

*Experimental runs*

A total of eleven experiments with duration of two and three hours were conducted in the laboratory (Table 1). The sequence of apertures and closure of faucets in a water distribution line, generated using the discrete demand model, were reproduced during the experiments. A centrifugal pump supplied water to the pipe system. The main pipe consisted of a 94.94 m long and 0.0508 m (2 inches) nominal diameter, PVC-SCH 40 pipe. Uniform sand grains were glued to the interior pipe wall using epoxy to create the roughness effect. Ten "household" connections were represented by 0.01905 m branch pipes, equally-spaced along the main pipe. The connections are separated 8.2 m and each represents a house along a distribution line (Figure2). Household flow meters provided the total flow demanded during a simulation period at each house. The total volume of water was read directly of the "household" water meters at the end of the experiments.

One pressure transducer was located at the upstream end of the pipe, and the pressure was recorded continuously during the experimental run. This data was collected using a Data Acquisition System at a sample frequency of 10 Hz. An ultrasonic flowmeter was installed at the downstream end of the main pipe for continuous measurement of the outflow.

*Verification of the computer algorithm*

A computer simulation was prepared to predict the water consumption in the households in the water distribution lines. The times between openings and the duration of the faucets, previously used in the laboratory, and the pressures history at the upstream end was input data to the program.

The measured and computed discharge flow at the downstream end of the pipe were compared to determine the capability of the model for realistic micro-scale computer simulation (Figure 3 and Figure 4).

*Conclusions*

Table 1 presents the parameters used for the Exponential, Weibull and Log-Normal distributions, and compares the measured and computed outflow volume at the downstream end. Eleven experiments were run using the Exponential, Weibull and Log-Normal probabilistic models. The distributions produced error less than 7%. These tests were performed with short opening times (3, 6 and 12 minutes) indicating that the hydraulic model responds to fast valve operations. The main conclusions of this part of the research are:

1. The combination of hydraulic and probabilistic model accurately predicts the measured volume.
2. The simulation results show a very similar pattern compared with the tendency of the real flows. Therefore, the water demand at each valve is similar to the ones obtained in the laboratory.
3. The model presented herein has the potential to estimate the water consumption in residential areas and, at the same time, simulate the behavior of the fluid under unsteady flow conditions.

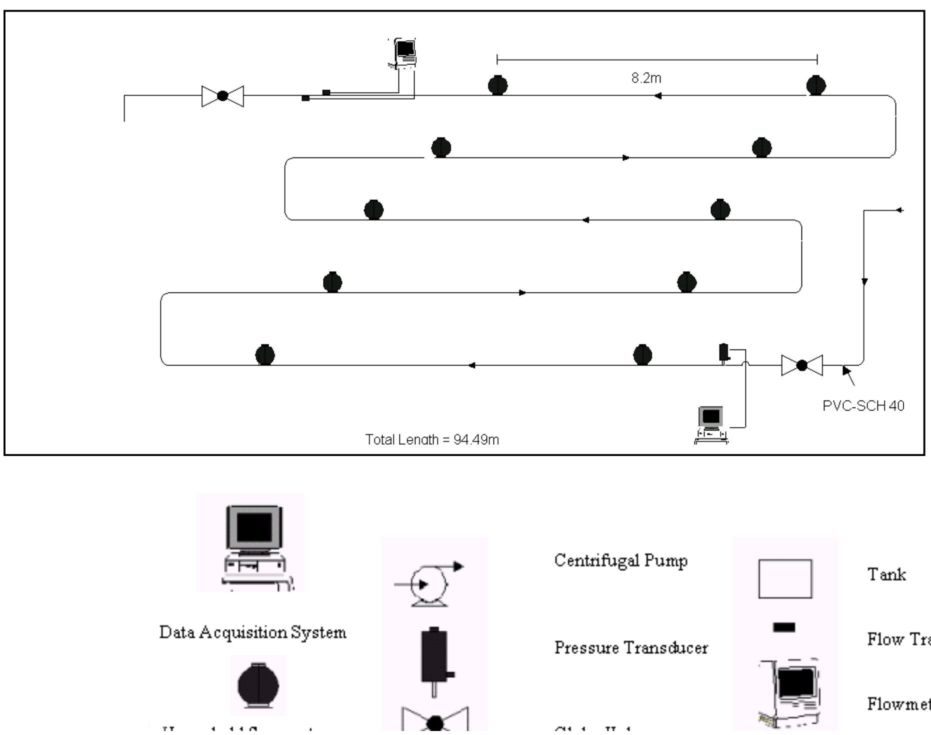



Figure2. General schematic of the system installed in the laboratory

Table 1. Experiments with Exponential, Weibull, and , Log-Normal Distributions

| Experiments | *Time between opening (min)* | *Mean duration (sec)* | *Distribution of Opening Duration* | *Number of valves* | *Measure volume ($m^3$)* | *Computed volume ($m^3$)* | *Percent error (%)* |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 40 | Exponential | 9 | 37.32 | 37.17 | 0.42 |
| 2 | 6 | 20 | Weibull | 5 | 38.44 | 38.66 | 0.54 |
| 3 | 3 | 20 | Exponential | 5 | 39.53 | 39.32 | 0.55 |
| 4 | 3 | 20 | Weibull | 9 | 39.54 | 37.15 | 6.04 |
| 5 | 3 | 40 | Weibull | 5 | 37.88 | 37.45 | 1.13 |
| 6 | 6 | 40 | Exponential | 5 | 36.56 | 37.54 | 3.22 |
| 7 | 6 | 20 | Exponential | 9 | 27.02 | 27.01 | 0.04 |
| 8 | 6 | 180 | Log-Normal | 5 | 26.39 | 26.42 | 0.03 |
| 9 | 12 | 180 | Log-Normal | 5 | 24.30 | 24.83 | 2.19 |
| 10 | 12 | 180 | Log-Normal | 10 | 21.45 | 21.44 | 0.06 |
| 11 | 6 | 180 | Log-Normal | 5 | 24.87 | 24.89 | 0.08 |

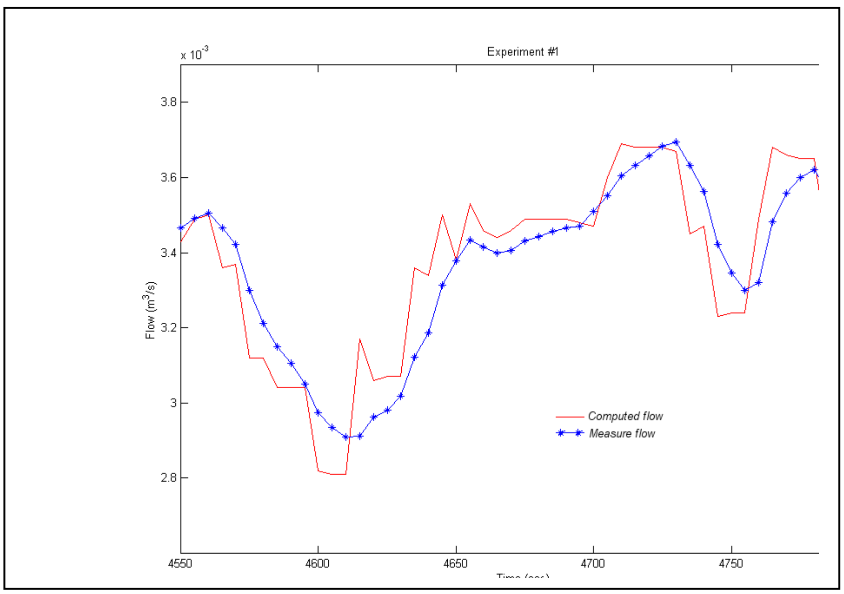



Figure 3. Measured and computed flows

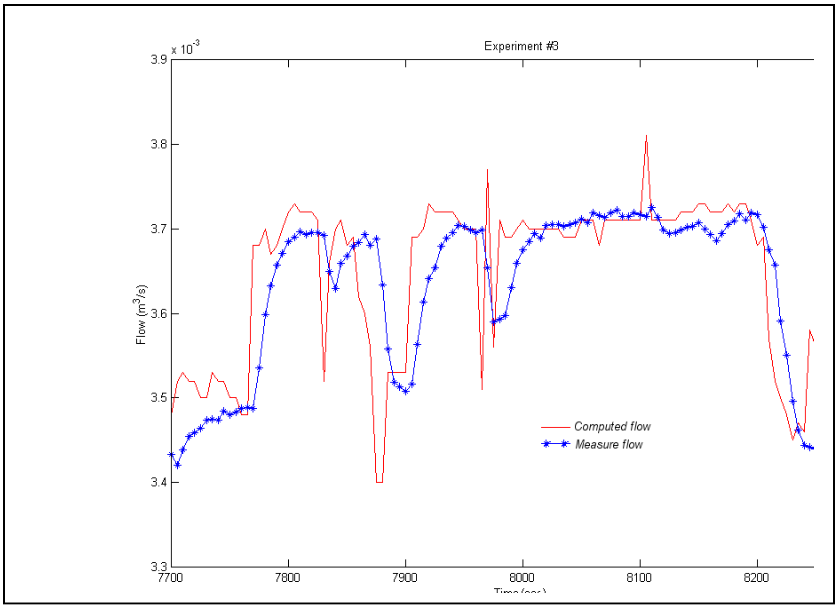


Figure 4. Measured and computed flows

**Present work**

At the present the experimental part in the laboratory has finished. The part that left if the surveyor part in which the pressure transducer and the flowmeter are installed in different houses to obtain data of the flow water used at different days and at different time of the day. This data will serve to generate a probabilistic demand model to obtain an approximate time between openings and duration of the apertures of the valves in a real neighborhood. After the probabilistic model has been set, simulations with the computer algorithm will be done to approximate a hypothetical consumption of water in a real neighborhood.

## References


Banks, J., J.S. Carson and B. Nelson. 1995. *Discrete-Event System Simulation.* $2^{nd}$ Ed. Prentice Hall, New Jersey.

Chaudhry, MH. 1987. *Applied Hydraulics Transients*. $2^{nd}$ Ed. Van Nostran Reinhold, New York, N.Y.

Collazos, L. 1999. "Análisis Experimental de un Modelo de Flujo Distribuido para Estimar Volúmenes de Consumo de Agua". MS tesis, Universidad de PuertoRico, Recinto Universitario de Mayagüez.

Silva-Araya, W. F. and Durán, M., 1998. "Distributed Demand Model for Estimation of Water Consumption in Pipe System", *Proc. Third Intl. Symposium of Tropica Hydrology*, AWRA, Puerto Rico.

# Information Transfer Program

One of the goals of the PRWRERI is to disseminate information and knowledge collected from the numerous research projects conducted by its researchers. This is accomplished in different ways. The Institute has established and hosts the Caribbean Islands Water Resources Congress which is held every two or three years in a Caribbean island. This fiscal year, the sixth congress was held in Mayagüez, Puerto Rico. This activity attracts water professionals from the Caribbean region and other parts of the world. Other modality to disseminate this information is through short professional courses. The Institute funded the Center for Professional Development three years ago and has offered a variety of course in different fields of the water resources area. Courses in hydrology, hydraulics, geomorphology, GIS, to mention some of them, have been offered and continuing education credits have been awarded. This year, the institute offered one of these course in Central America for the Government of Guatemala. Other courses are being scheduled for Honduras and Costa Rica.

## Basic Information

| | |
|---|---|
| **Title:** | Sixth Caribbean Islands Water Resources Congress |
| **Start Date:** | 3/1/2000 |
| **End Date:** | 2/28/2001 |
| **Descriptors:** | Water Resources, Congress, Infromation transfer |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Jorge Rivera-Santos, Walter F Silva |

## Publication

## Problem and Research Objectives:

The Sixth Caribbean Water Resources Congress was on February 22-23 at the Mayagüez Resort & Casino, Mayagüez, PR. It was a conference about some topics like: Limnology, Extreme Hydrologic Events, Erosion, Sedimentation and Geomorphology, and Climate in the Tropics. Also, such like: Surface Water Quality and Water Resources Information and Education. About 70 persons participated in the activity and some of them were professionals from the USGS of Puerto Rico, CSA Group, US Forest Service, The Highway Authority of Puerto Rico, professors from the University of Puerto Rico at Mayagüez, Arecibo and Humacao, the University of Florida, and the Polythecnic University of Puerto Rico and the Metropolitan University of Puerto Rico. Some of them were also lectures.

## Methodology:

Sets of abstract submitted were chose to participate in the Congress. Some of them were improved to maintain the requisites for the congress rules. After that, the participants submitted the initial version of their papers to be evaluated by different professionals of the related topics. Again, some of them were improved to be prepared to the final version of the papers. Next, a CD was prepared for each participant of the Congress in which all papers were viewed in an html format. The conference was held at the Mayagüez Resort and Casino of Mayagüez in which the participants had the opportunity to share in a cocktail, one day before the Conference. The two days that the activity last, the participants had the opportunity to eat coffee breaks and lunch at the Resort and enjoy the facilities of the area. Special rates were obtained to the participants that stayed those days in the hotel.

## Principal Findings and Significance:

The Six Caribbean Island Water Resources Congress was held in Mayaguez, Puerto Rico, from February 22-23, 2001. The meeting gathered 70 individuals, most of them, professionals of the water resources field. A total of 37 professional papers were presented and published in the conference proceedings in a compact disk (CD) version.

The flowing tables and charts present the distribution of participants by institution represented in the congress.

**Table 1. Participants by institution represented in the congress.**

| Institution | participants | (%) |
|---|---|---|
| UPR-Mayagüez-Professors | 12 | 17.1 |
| UPR-Mayagüez-Students | 11 | 15.7 |
| USGS | 8 | 11.4 |
| CSA Architects and Engineers | 5 | 7.1 |
| Federal Highway Administration | 4 | 5.7 |
| Metropolitan University (UMET) | 3 | 4.3 |
| USDA | 3 | 4.3 |
| Puerto Rico Water Company | 2 | 2.9 |
| Interamerican University – San Juan Campus | 2 | 2.9 |
| Polytechnic University | 2 | 2.9 |
| Interamerican University – Bayamón Campus | 2 | 2.9 |
| University of Virgin Islands | 2 | 2.9 |
| Infrastructure Financing Authority (AFI) | 1 | 1.4 |
| CAPR | 1 | 1.4 |
| CMA Architects and Engineers | 1 | 1.4 |
| Environmental Protection Agency | 1 | 1.4 |
| HP Subcontractor Pro | 1 | 1.4 |
| PR Water Environmental Association | 1 | 1.4 |
| PRWEF | 1 | 1.4 |
| Agriculture Extension Service - San Juan | 1 | 1.4 |
| Interamerican University – Ponce Campus | 1 | 1.4 |
| University of Central Florida | 1 | 1.4 |
| UPR Sea Grant Program | 1 | 1.4 |
| UPR-Aguadilla | 1 | 1.4 |
| UPR-Arecibo | 1 | 1.4 |
| UPR-Humacao | 1 | 1.4 |
| Total | 70 | 100 |

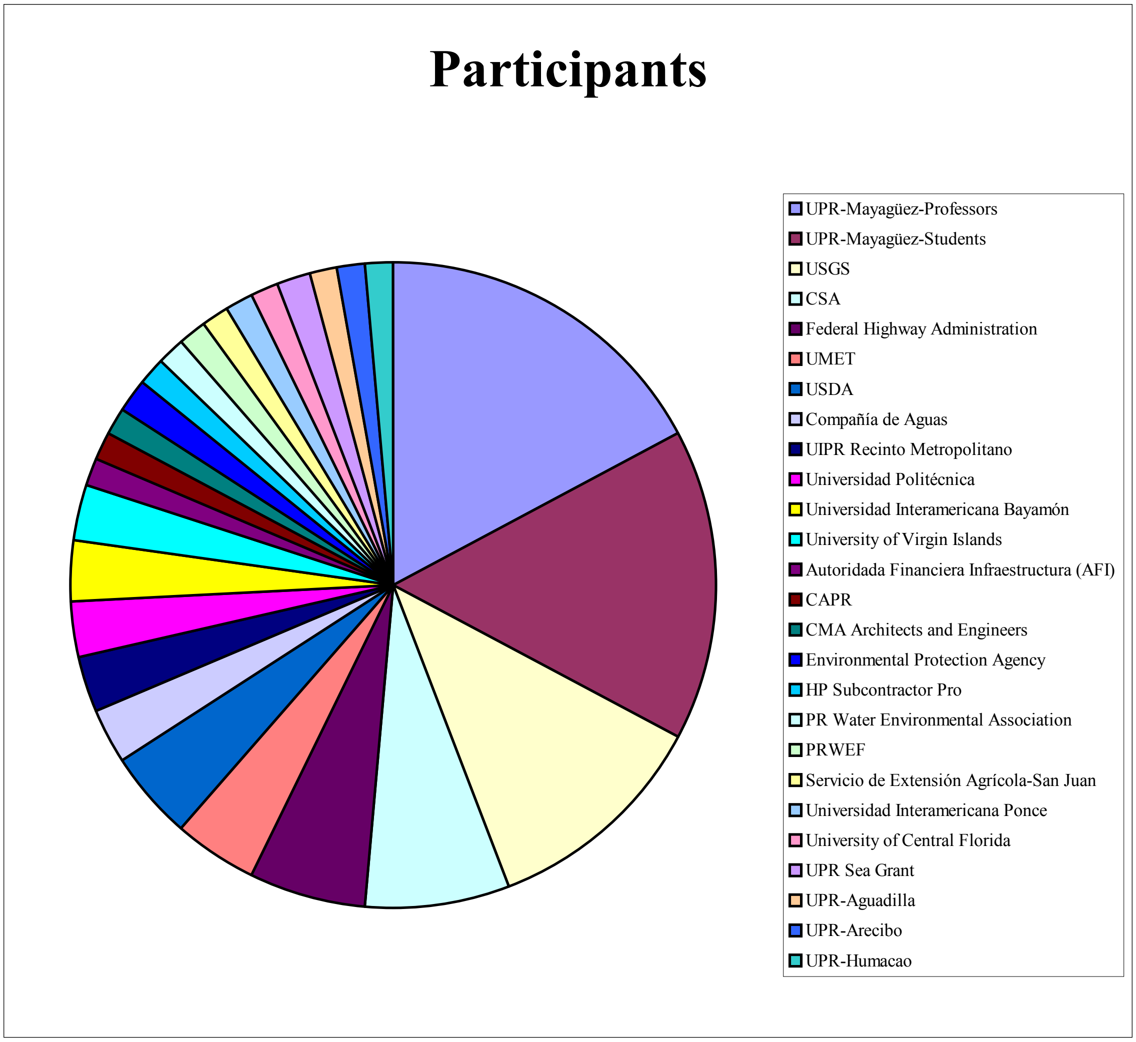



**Figure 1. Participants by institution represented in the congress.**

**Table 2. Papers distributed by institutions.**

| Institution | Papers | (%) |
|---|---|---|
| UPR-Mayagüez | 18 | 24.3 |
| USGS | 11 | 14.9 |
| CSA | 3 | 4.1 |
| USDA Forest Service | 1 | 1.4 |
| University of Central Florida | 1 | 1.4 |
| UPR-Humacao | 1 | 1.4 |
| UPR-Arecibo | 1 | 1.4 |
| University of Costa Rica | 1 | 1.4 |
| Total | 37 | 100 |

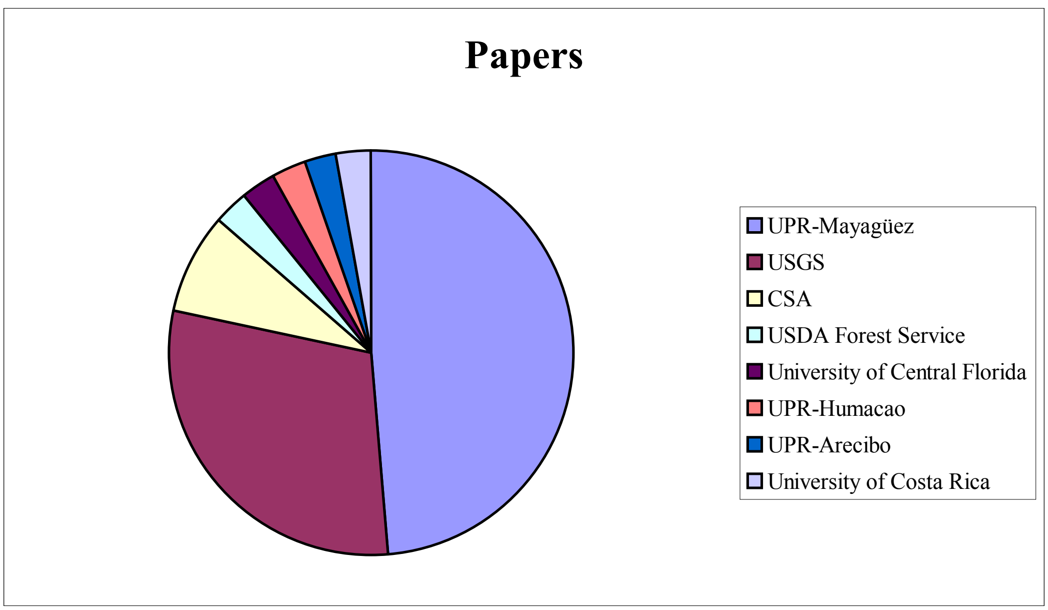



**Figure 2. Papers distributed by institutions.**

As it can be observed from the charts and tables, most of the participants were from the University of Puerto Rico at Mayagüez. Many students participated in the activity as well. Other parties that participated included the USGS, who were the second group with more participants in the activity, other units of the University of Puerto Rico, private consulting firms, the University of Costa Rica, and the University of Central Florida. A total of 70 persons participate in the Congress. A total of 37 papers were presented and published in the proceedings of Congress.

## Basic Information

| | |
|---|---|
| **Title:** | Research on State of the Art Techniques to Assess and Design River Stability Measures |
| **Start Date:** | 10/1/2000 |
| **End Date:** | 5/31/2001 |
| **Descriptors:** | Geomorphology, bank stabilization, erosion control, short course |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Walter F Silva, Jorge Rivera-Santos |

## Publication

**Problem and Research Objectives**

A research on state-of-the-art techniques to assess and design river stability measures was conducted during this project. The literature research was summarized and presented in class material, prepared in Spanish language, for use by the USACOE in technology transfer projects in Latin American countries.

The course material consisted of conference presentations, manual translations, computer programs demonstrations, and explanation of some design calculations. These material was used in an intensive short-course on Streambank Stabilizations Techniques offered in Guatemala from April 16 to 27, 2001. The course was supplemented by conferences from gabion companies, geo-hydrology of Guatemala, field trips and case-study presentations.

The course was offered to a very motivated group of civil and agricultural engineers. A total of 20 students attended the conferences. Their interest in learning was demonstrated by the continuous participation with questions, discussions and case stories heard during the class.

The evaluation shows that over 80% of the attendants were satisfied beyond their expectations, and, consequently, the instructors were very well evaluated. The use of the printed material was found very useful to supplement the conferences.

The objectives of this research and technology transfer project were

1. To conduct a literature research, compile and present information on State-of-the-Art measures and techniques for channel and river assessment and design.
2. Include the findings in conferences and class material, prepared in Spanish language. This material will be available for use by the U. S. Corps of Engineers (USACOE) in technology transfer projects in Latin American countries.
3. To use the educational material in an intensive course on channel stabilization techniques in Guatemala, Central America. This course was offered in April 2001.

**Methodology**

The following procedure was followed during the project duration

1. The Principal Investigator (P.I), personnel from the Waterways Experiment Station (WES) of the U.S. Army Engineer Research and Development Center (ERDC) and, one external consultant, met to discuss the topics included in the research and technology transfer component. Course content, course requirements, layout and instructional materials were outlined during this visit. These meetings were held at WES in Vicksburg, Mississippi. This activity coincided with a Streambank Stabilization Course offered by WES in October 2000 and attended by the P.I.

2. The consulted literature was collected from WES publications and reports, books, and reports generated by the USACOE from the recent experience with channel protection works in Guatemala. The list of references is presented in this report.

3. The technical terminology was adapted to Spanish language. Some new technical terms were introduced for the first time in Spanish, and native personnel from Guatemala was consulted to cultural differences in language, teaching techniques, instructional materials and engineering practice.

4. One expert in streambank stabilization techniques, one consultant in hydrology of Guatemala and the P.I. spent one week for reconnaissance of streams and existing bank stabilization projects in this country. During the trip the experts became familiar with the stream processes and stabilization measures used in the Guatemalan streams. Existing and under-construction bank stabilization projects were visited and their performance was documented. Several case studies from this visit were incorporated into the course material and conferences.

5. A series of conferences were prepared in Spanish language. A preliminary translation of the Riprap Design Procedure Manual used by the USACOE ( included in EM-1110-2-1001) was offered as class material.

6. One expert from WES and the P.I. traveled to Guatemala to offer the course. All lectures, handouts, instructional materials and hand-on experience workshops were provided to the class. The course lasted 10 days and included class lectures, conferences by an expert in

geo-hydrology of Guatemala, representatives of three gabion companies and two field trips to project sites. The intensive course was offered from April 16 to 27, 2001.

**Principal Findings and Significance**

The literature consulted for this project consisted of handouts from WES courses in Streambank and Erosion Control course, the WES Stream Investigation and Streambank Stabilization Handbook, several reports on studies on the Motagua and Polochic rivers done by the USACOE in Guatemala after the disaster of Hurrican Mitch, and other references included in the list of References.

*Streambank Course*

The course was offered to a very motivated group of civil and agricultural engineers. A total of 20 students attended the conferences. Their interest in learning was demonstrated by the continuous participation with questions, discussions and case stories heard during the class.

The evaluation shows that over 80% of the attendants were satisfied beyond their expectations, and, consequently, the instructors were very well evaluated. The use of the printed material consisted of photocopies of Power Point presentations and a translation of the riprap design procedure of the USACOE (Chapter 3, EM-1110-2-1601). All the class (100%) found them useful to supplement the conferences.

The course duration was considered from “good enough” to “too short”. Therefore, even though the course lasted for two weeks, the class kept the interest until the last day; in general, the course was considered “Excellent” or “Above Average”. The participants are willing to recommend it to other colleagues.

The field visits were very instructive. The group demonstrated much interest and participation, particularly in the second visit to streambank works in several tributaries of the Motagua river.

The case studies presentations were and excellent opportunity for the application of the concepts learned during the course. The students were divided in five teams. Each group presented a case study and possible solutions to the problems observed during the field visit. Detailed results of the course evaluation form are given in the Appendix.

Three gabions companies were invited to make presentations of up to four hours. Much importance was given to gabions because of their extensive use in protection works in Guatemala. Each company presented it products and provided general design advise. Some of the conferences were considered too long and slightly repetitive; however, they presented the opportunity to answer many questions related to these highly used stabilization structures.

This experience suggested that latinamerican engineers are willing to learn and improve if they are giving the opportunity. They requested more courses in hydrology, hydraulics, and geomorphology.

***Acknowledgement***

The P.I. wishes to express his deeply and sincere thanks to the personnel of the USACE Professional Development Center and of the Vicksburg District, in Mississippi, particularly to David Biedenharn and Dave Derrick for their support during this project. He also thanks the consultants Charles Elliott and Carlos Muñoz for their participation during the reconnaissance trips, the preparation of the class material and the classes in Guatemala.

Personnel from AID in Guatemala, MAGA, CIPREDA, ANACAFE and the USACOE Office in Guatemala, helped to make this course a very successful experience. Thanks to all of them.

***References***

1. US Army Corps of Engineers Professional Development Support Center (2000). Streambank Protection Course, October 16-20, Class Handouts.
2. Fischenich, J. and Freeman, G. (not dated),Ecological Impacts of Bank Stabilization Using Gabions, Motagua River, Guatemala.
3. US Army Corps of Engineers (2000). Reconnaisance Report: Hurricane Mitch Rehabilitation and Reconstruction Study – Polochic Basin, Guatemala.
4. MAGA, USACOE, AID (2000). Reporte de Viabilidad: Estudio Sobre Rehabilitación y Reconstrucción después del Huracán Mitch, Cuenca del Río Motagua, Guatemala, Vol I y II.

5. MAGA, USACOE, AID (2000). Proyecto de Demostración para Rehabilitar los Sistemas de Irrigación Menores del Río Teculután, Guatemala.
6. Biedenharn, D.; Elliot, C. M. and Watson, C. (1997) The WES Stream Investigation and Streambank Stabilization Handbook.
7. Watson, C; Biedenharn, D., Scott, Stephen H. (1999) Channel Rehabilitation: Processes, Design and Implementation, USACOE.
8. Thorne, C.R. (not dated), Manual para el Reconocimiento de Ríos (translated to Spanish by B. Callen and O. Juarez).
9. USACOE (1995) Hydraulic Design of Flood Control Channels (EM-1110-2-1001), ASCE.
10. USACOE (1997) Channel Stability Assessment for Flood Control Projects (EM-1110-2-1418), ASCE.

APPENDIX:

Results of Course Evaluation

**1. ↵Did the course fullfilled the objetives?**

| More than expected | What we expected | Less than we expected |
|---|---|---|
| 15 - ***79%*** | 4 - ***21%*** | 0 - ***0%*** |

**2. ↵How do you grade the instructors?(do not include the gabions representative)**

| Excelent | Above Average | Average | Below Average | Poor |
|---|---|---|---|---|
| 18 - ***94.7%*** | 1 - ***5.3%*** | 0 - ***0%*** | 0 - ***0%*** | 0 - ***0%*** |

**3. ↵Were the manuals useful in class?**

| Very useful | Useful | A little useful | Not useful |
|---|---|---|---|
| 14 - ***73.7%*** | 5 - ***26.3%*** | 0 - ***0%*** | 0 - ***0%*** |

4. ↵What do you think about the duration of the course?

| Too long | Just right | Too short |
|---|---|---|
| 0 - ***0%*** | 15 - ***79%*** | 4 - ***21%*** |

5. In general, how do you evaluate the course?

| Excellent | Above average | Average | Below average | Poor |
|---|---|---|---|---|
| 15 - ***79%*** | 4 - ***21%*** | 0 - ***0%*** | 0 - ***0%*** | 0 - ***0%*** |

6. Will you recommend this course to other colleagues or engineers?

| Very much | Regular | Never |
|---|---|---|
| 18 - ***94.7%*** | 1 - ***5.3%*** | 0 - ***0%*** |

7. Evaluate the sessions according to the topics presented every day (1 for the lowest, 5 for the highest).

lowest--------------------> highest

| | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|
| **Fundamentals of Hydrology (day 1)** | 0 - ***0%*** | 1 - ***5.3%*** | 2 - ***10.5%*** | 6 - ***31.6%*** | 10 - ***52.6%*** | 19 |
| **Fundamentals of Hydraulics (day 2)** | 0 - ***0%*** | 0 - ***0%*** | 3 - ***15.8%*** | 8 - ***42.1%*** | 8 - ***42.1%*** | 19 |
| **Fundamentals of Fluvial Geomorphology (day 3)** | 0 - ***0%*** | 0 - ***0%*** | 1 - ***5.3%*** | 5 - ***26.3%*** | 13 - ***68.4%*** | 19 |
| **Field Visit No. 1 (day 4)** | 0 - ***0%*** | 0 - ***0%*** | 3 - ***15.8%*** | 9 - ***47.4%*** | 7 - ***36.8%*** | 19 |
| **Principles of the Erosion Protection (day 5)** | 0 - ***0%*** | 0 - ***0%*** | 1 - ***5.3%*** | 3 - ***15.8%*** | 15 - ***78.9%*** | 19 |
| **Geology and Hydrology of Guatemala (day 5 and day 6)** | 0 - ***0%*** | 0 - ***0%*** | 2 - ***10.5%*** | 9 - ***47.4%*** | 8 - ***42.1%*** | 19 |
| **Stabilization Methods (día 6)** | 0 - ***0%*** | 0 - ***0%*** | 1 - ***5.3%*** | 3 - ***15.8%*** | 15 - ***78.9%*** | 19 |
| **Design of Riprap (day 7)** | 0 - ***0%*** | 0 - ***0%*** | 0 - ***0%*** | 6 - ***31.6%*** | 13 - ***68.4%*** | 19 |
| **Structures of Gradient Control (day 7)** | 0 - ***0%*** | 0 - ***0%*** | 1 - ***5.3%*** | 6 - ***31.6%*** | 12 - ***63.1%*** | 19 |
| **Presentations of Gabions companies (days 7 and 8)** | 0 - ***0%*** | 0 - ***0%*** | 0 - ***0%*** | 11 - ***57.9%*** | 8 - ***42.1%*** | 19 |
| **Field Visit No. 2 (day 9)** | 0 - ***0%*** | 0 - ***0%*** | 0 - ***0%*** | 2 - ***10.5%*** | 17 - ***89.5%*** | 19 |
| **Presentations and Discussions on case studies (day 10)** | 0 - ***0%*** | 0 - ***0%*** | 0 - ***0%*** | 6 - ***31.6%*** | 13 - ***68.4%*** | 19 |
| **Total** | 0 | 1 | 14 | 74 | 139 | 228 |

## 8. In the space below, please tell us any additional comment about your impressions and suggestions for this course.

Very professional. Very important for engineers. Well organized. Appropriate content. Instructors very well qualified. Well planned. Should be longer.
Similar courses should be done for continuing education of the professionals in the country, very good, the knowledge is necessary in this area.
I got the basis for design, excellent, include more about the computer programs, do something to refresh and reinforce the principles learned.
Is important to keep international contact with other professionals in the area to give continuity to the topics
The knowledge learned help to the solution of many problems in our country. Add more field activities.

## 9. Tell us if you would like to receive more lessons or deeper knowledge in some of the topics covered in this course ?

Design of riprap structures, design of dikes, design of walls, design of dams, trenchfills, windrow design, application of computer models from USACOE (HEC-RAS, HEC-HMS), hydrology of Guatemala, hydraulics, geomorphology, methods of stabilizations, design of gradient control structures, vegetative methods more recommended for Guatemala, structures for the protection of water sources.

## Basic Information

| | |
|---|---|
| **Title:** | Updated UIC Inspector Training Course - Spanish version |
| **Start Date:** | 8/7/2000 |
| **End Date:** | 8/31/2000 |
| **Descriptors:** | Groundwater, Well inspection, SDWA, Short course |
| **Lead Institute:** | Water Resources Research Institute |
| **Principal Investigators:** | Jorge Rivera-Santos |

## Publication

## Problem and Objective

The Underground Injection Control (UIC) Program has evolved since the last time an Inspector Training Course was offered in San Juan, Puerto Rico. The last training course took place in 1992. After eight years, several changes and amendments have been made to the program. This made necessary the offering of a new updated training course for local government officials charged with the responsibility of inspecting class V wells in Puerto Rico. This responsibility lies primarily on the Puerto Rico Environmental Quality Board (PREQB), but personnel from other agencies, such as the Department of Natural and Environmental Resources (DNER), the Puerto Rico Aqueduct and Sewer Authority (PRASA), the Department of Agriculture of Puerto Rico, Department of Health, etc., may gain benefit from the course. The updated course was offered during August 9-11, 2000, in San Juan Puerto Rico.

The objective of this project is to update the Inspector Training Course and included the latest amendments of the law. The course should be administered to all government personnel interested in being certified as UIC program well inspector.

### *Methodology*

The course was offered in San Juan, Puerto Rico, which ensured a bigger audience, since most of the potential target agency offices were within the San Juan Metropolitan Area (SJMA). A centric location for the course was selected at the Central Administration facilities of the University of Puerto Rico at Río Piedras. These facilities are located at the Botanic Gardens of the Agricultural Experimental Station, a well-known place in San Juan. The air-conditioned classroom, called "la terraza," was comfortable and big enough to accommodate over one hundred seated people with tables for writing in a classroom environment. The location had guarded parking lots and cafeteria facilities.

The course, which was offered in Spanish, had duration of three days. The first and second days were dedicated to theory with a pre-examination administered the first day during the morning. The last day included a field trip to a class V well located in the facilities of a small industry in the SJMA (see Appendix A for the Spanish version of the course schedule. An English translation is also included in the same appendix). Monitoring techniques and sampling equipment were demonstrated during the field trip. Laboratory personnel from the Puerto Rico Environmental Quality Board (PREQB) with vast experience in field monitoring and sampling were in charge of the demonstration. Transportation was provided for all attendees to and from the well site. The field trip was conducted during the morning and a recap session was held after lunch back in the classroom and prior to the final test. The course closed with a final test administered to all students.

All course material was developed and prepared in Spanish by four instructors. Two of them are faculty members at the University of Puerto Rico at Mayaguez (Dr. Felix Román from the Chemistry Department and Dr. Jorge Rivera from the Environmental Engineering Area of the Civil Engineering Department and Director of the Puerto Rico Water Resources and Environmental Research Institute), one from the Inter American University at San Germán (Dr. Graciela Ramírez, Director of the Center for Environmental Education, Conservation, and Interpretation, CECIA by its acronyms in Spanish) and one from the University of Puerto Rico at Río Piedras (Dr. José Molinelli, Director of the Environmental Science Department).

A Spanish version of the student manual was provided by EPA's office in New York. The Student Manual was updated with the inclusion of an addendum, which included the latest changes and amendments of the UIC program as of August 2000. A Spanish version of the addendum can be examined in Appendix B of this report. Other material handed out in form of loss leaves can be also examined in Appendix C.

The multiple-choice final test was administered in Spanish. The EPA's office in New York sent us a copy of the test used the last time the course was offered in Puerto Rico (1992). That test was carefully studied and compared to the information the Spanish version of the manual included. Those questions that were out of date or which the information necessary to answer them was no included in the manual and course material were discarded. New questions were added to incorporate new amendments of the program. Areas tested included regulatory structure, UIC program policy and structure, Class V wells, sampling Class V wells, and UIC inspections. The following table describes the composition of the exam. A Spanish version of the UIC test can be reviewed in Appendix D.

**Table 1. Composition of the final exam.**

| Theme | Number of questions | Points for this field |
|---|---|---|
| Regulatory Structure | 17 | 22 |
| Policy and Structure of UIC | 7 | 13 |
| Class V Wells | 12 | 12 |
| Sampling Class V Wells | 8 | 8 |
| Class V Well Inspections | 13 | 17 |
| Totals | 57 | 72 |

A total of 57 questions tested the knowledge acquired by the students in the various themes included in the course. The maximum number of points a student could earn was 72 points for a 100% grade.

At the last day of the course, after the final exam was offered, an evaluation sheet was passed out and the student comments and remarks were collected. This evaluation consisted of 10 questions regarding the nature of the course as well as the methodology and techniques used to present the course material. The student was given the opportunity to make comments and to suggest how the course could be improved.

### *Principal Findings and Significance*

The training course was offered as scheduled on August 9 through August 11, 2000. One hundred people enrolled, of which five of them did not take the final examination. The attendees were from different government agencies, including both, federal and state agencies, as well as from municipal governments and the state university. The following table summarizes the number of enrolled students by agency.

**Table 2. Classification of attendees by agency.**

| Agency | Number of Employees | Agency Type |
|---|---|---|
| Solid Waste Management Authority (SWMA) | 5 | State |
| PR Electric Power Authority (PREPA) | 2 | State |
| Public Building Authority (PBA) | 1 | State |

| | | |
|---|---|---|
| PR Department of Agriculture (PRDA) | 5 | State |
| Regulations and Permits Administration (RPA) | 6 | State |
| PR Aqueducts and Sewer Authority (PRASA) | 2 | State |
| PR Water Company (PRWC) | 9 | State |
| Transportation and Highways Authority (THA) | 1 | State |
| PR Health Department (PRHD) | 4 | State |
| Environmental and Natural Resources Department (ENRD) | 4 | State |
| PR Environmental Quality Board (PREQB) | 43 | State |
| OMEP | 1 | State |
| Housing Department (HD) | 1 | State |
| University of Puerto Rico – Agricultural Extension Service (UPR-AES) | 1 | State |
| University of Puerto Rico – Ponce Campus | 1 | State |
| University of Puerto Rico – Central Administration | 2 | State |
| Environmental Protection Agency (EPA) | 4 | Federal |
| NAVY | 3 | Federal |
| US Geological Survey (USGS) | 1 | Federal |
| Municipality of Aguada | 2 | Municipal |
| Municipality of Caguas | 1 | Municipal |
| Municipality of Florida – Public Works Department | 2 | Municipal |
| Total Number of Attendees | 100 | -- |

The attendees to the course represented a total number 16 state government agencies. These included three dependencies of the University of Puerto Rico. The Environmental Quality Board was the state agency with the largest number of employees attending the course. Also, three federal agencies and three municipal government agencies were represented in the course. This makes a total of 22 government agencies attending the course. The enrollment list can be reviewed in Appendix E.

Only 95 of the 100 enrolled students were examined at the end of the training course. Five of the students did not show up during the examination period (see the attendance in Appendix F). The passing grade was fixed at 60% by EPA office. Only three students did not pass the examination. Their grades were below the minimum passing grade of 60%. Students' grades can be reviewed in Appendix G.

A frequency analysis of the distribution of the grades was carried out. This analysis helps understand how effective was the teaching methods used during the course. Figure 1 presents the results of this analysis. From this figure we can infer that the majority of students got grades between 89 - 80% and 79 - 70%. The frequency for these two classes was 0.45 and 0.39, respectively, representing 84% of all students. This means that the students could assimilate the material taught in the course. Only three students did not pass the test.

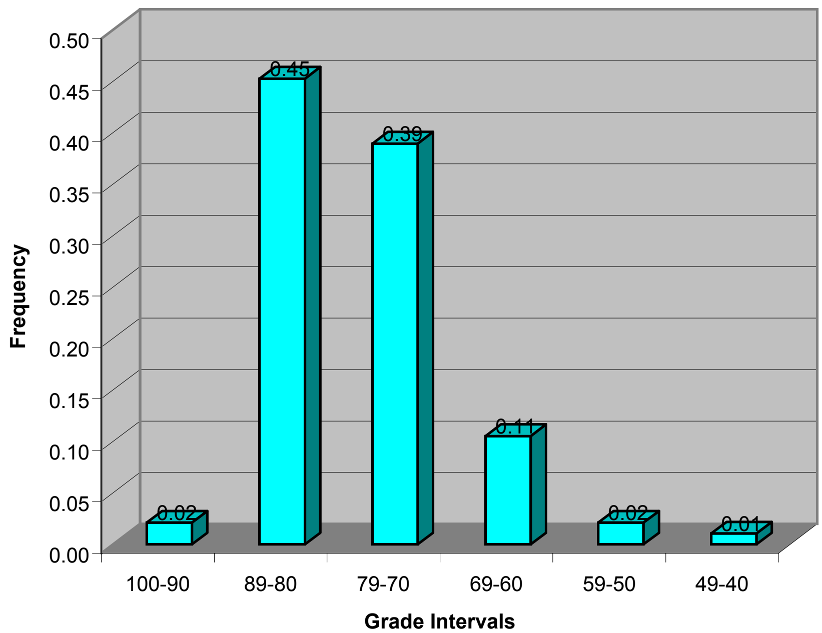



**Figure 1. Grade frequency diagram.**

As mentioned before, an evaluation sheet was given to the students to allow them to express their feeling with respect to the way the course was handled. The evaluation sheet contained ten questions designed to get information about course content expectation, the appropriateness of the equipment used and material handed out, the way the course was administered, the suitability of the location, and the quality of the snacks provided during the breaks. Also, the students had the opportunity to write down recommendation, remarks, and suggestions in the space provided on the sheet.

A total of 91 completely answered evaluation sheets were collected. This represents a 91% of the roster, which makes possible to obtain meaningful results from a statistic analysis of the data. The evaluation sheet allowed the selection of one of five choices for each question. The lesser value (1) corresponded to a category of *deficient*, a value of 3 meant *adequate,* and the largest value (5) equaled a category of *excellent*. Each category (1 through 5) was totaled and the distribution frequency determined. The result of this analysis is presented graphically in Figure 2.

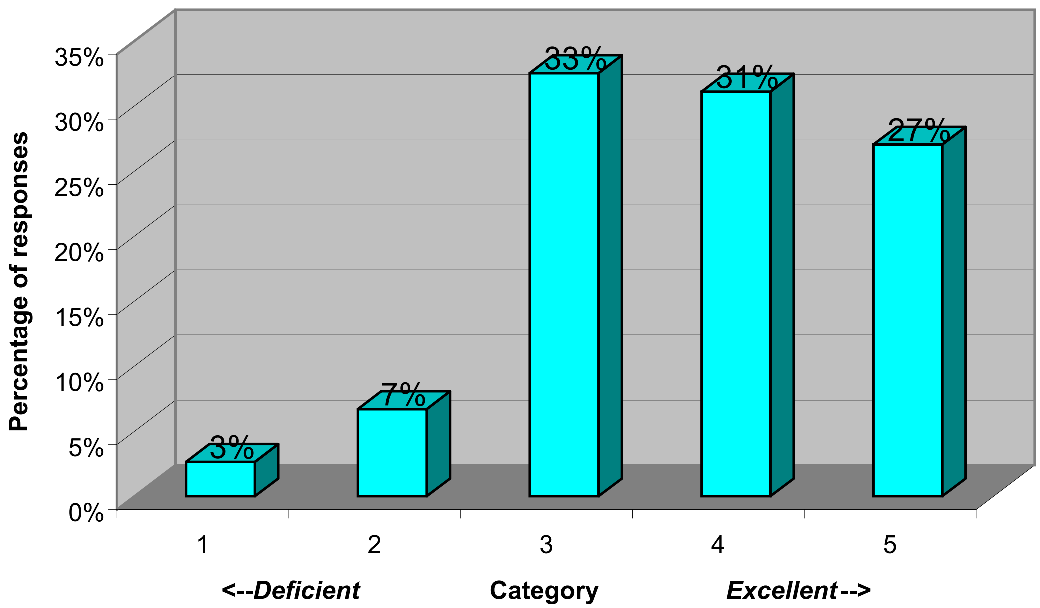
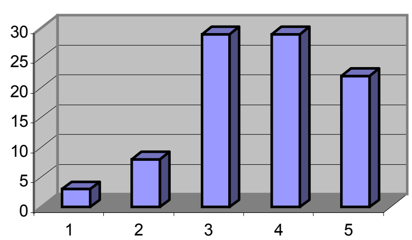
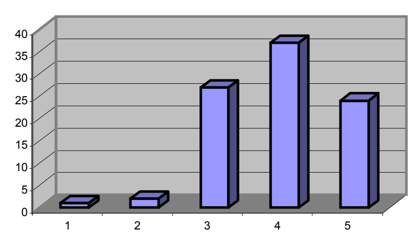


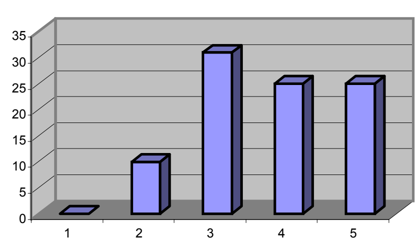

**Figure 2. Overall distribution of the answers on the evaluation sheet.**



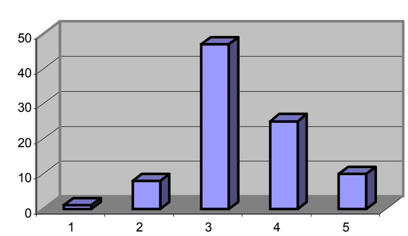

Question 1



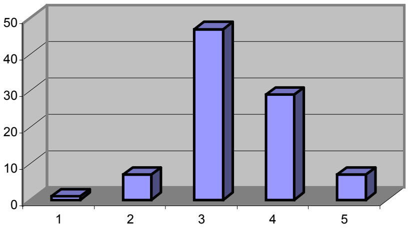

Question 6



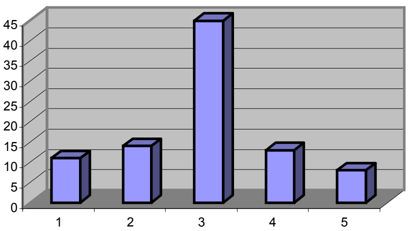

Question 2



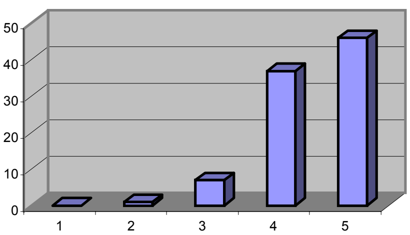

Question 7



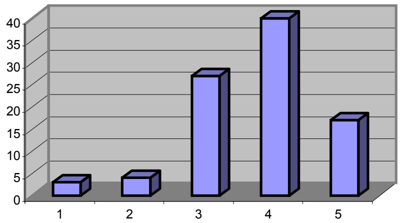

Question 3



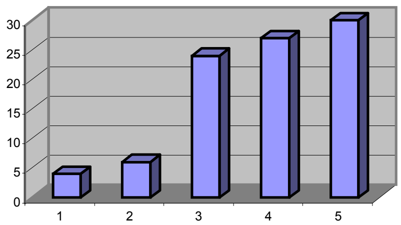

Question 4



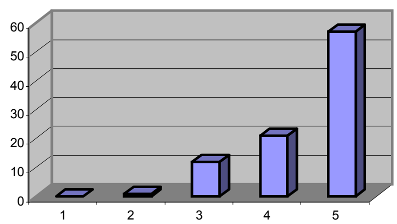

Question 5




Question 8




Question 9




Question 10

**Figure 3. Answer distribution from the evaluation sheet.**

From Figure 2 we can state that the majority of the students were satisfied with all aspects of the course. Most of the students gave a grade of adequate to excellent to the course. This represents 90% of all students. Figure 3 presents the response for each individual question.

Although the overall evaluation was more than adequate, there are three questions that deserve special attention. These are questions 3, 4, and 7. Question 3 deals with the technical level of the course. Apparently, the students expected a more technical in nature course. Since the background of the students was not known before hand, the course material was prepared keeping in mind a less technical audience.

Question number 4 has to do with the time allocated for the field trip. The students believe that more time should be dedicated to the field trip. Since we got more students enrolled in the course than expected (we planed originally for 60 students), the field demonstration was given twice during the time allocated for one demonstration. This was necessary because the group was bigger than planed and had to be split in two.

Question 7 asked for the suitability of the duration of the course and the speed in which the material was covered. Although adequate as per the students' answers, the feeling was that it was too much material for 2 days and a half. More time is necessary to cover the material and allow enough time for the students to clarify their doubts. One hundred students were too much for the time dedicated for the questions and answers sessions.

Appendix H contains a summary of the data collected from the evaluation sheets. In addition, at the end of this appendix, the Spanish version of the evaluation sheet can be reviewed.

## *Conclusions and Recommendations*

Overall, the update UIC training course was a success. The course was well accepted by the government agencies, either federal or state agencies. One hundred students enrolled in the course; 40 students over the original expectation. The course material was covered in two days, one morning was dedicated to a Class V Well site visit, and one afternoon was allocated to recap, question and answer session, and examination, for a total of three days. There were two students that did not show up during the course and only three did not show up during the examination period. That is five students of one hundred that did not take the exam.

The final exam was administered the last day. Ninety-five students were examined, of which only three did not approved. This represent 97% of examined students passing the test or, put in other words, 92% of the enrolled students passing the test.

The course evaluation showed that it fulfilled the students' expectations. The course overall evaluation was more than adequate as per the students answers. Some of the comments written by students in the evaluation sheets indicate that the course should be offered more frequently and more time allowed for the field visit.

The experience gained during the process of preparing and administering the course enables us to make the following recommendations.

1. A similar course, if offered in the future, will required at least three days to cover the technical material.
2. Allocate one day for field visit and examination.
3. Do not allow a roster larger than that planed ahead (50 students recommended). This will ensure the students will receive the attention they deserve, especially during the field trip. If the enrollment is more that 50 people, planed for a whole day field trip.
4. If more than fifty students are interested in the course, consider having two sessions of the course.
5. It will be very helpful knowing before hand the technical background of the students (scientists, engineers, etc.). This will determine the way the course material will be presented.
6. Enrollment should be managed by the same office that, or entity, that prepares the course material and administers the course.

# Appendix A

# Course Schedule

**(Spanish versions)**

## Programa de Control de Inyección Subterránea
## Curso de Adiestramiento
## para Certificación de Inspectores

Agosto 9-11, 2000
San Juan, Puerto Rico

Itinerario del curso

| Miércoles 9 de agosto de 2000 | | |
|---|---|---|
| 8:00am | Registro | |
| 8:30 | Bienvenida | Jorge Rivera-Santos, PRWRERI |
| | La Academia de Recursos de Agua de la EPA | Norma Ortega, EPA |
| | Programa de Control de Inyección Subterránea (CIS) – EPA | |
| | Programa de Control de Inyección Subterránea – Junta Calidad Ambiental | Denise Laabes, JCA |
| | Presentación de instructores<br>Objetivos del curso | Jorge Rivera-Santos |
| 9:00 | Pre-examen | |
| 10:00 | Receso | |
| 10:15 | Introducción a la hidrología de aguas subterráneas y geología de Puerto Rico | José Molinelli, UPRRP |
| 12:15pm | Almuerzo | |
| 1:15 | Discusión general del programa de CIS | Jorge Rivera-Santos |
| | Resumen del programa<br>Sistema de clasificación de pozos<br>Enmiendas al programa CIS | |
| 2:00 | Inspecciones de CIS | Graciela Ramírez-Toro, CECIA |
| | Resumen de la LAPS y sus enmiendas<br>Reglamentos y autoridad para efectuar inspecciones de la LAPS<br>Función del inspector<br>Responsabilidades del inspector | |
| 3:00 | Receso | |
| 3:15 | Acceso a Instalaciones | |
| | Consideraciones estatutarias<br>Consideraciones constitucionales<br>Estudio de casos<br>Denegación de entrada a una instalación | |
| 5:00 | Cierre del día | |

| Jueves 10 de agosto de 2000 | | |
|---|---|---|
| 8:00am | Seguridad en el Campo | Jorge Rivera-Santos |
| | Equipo de protección<br>Otras Medidas de Precaución | |
| | Pruebas de Integridad Mecánica | |
| | Registro de Pozo | |
| | Obturación y Abandono de Pozos | |
| 10:00 | Receso | |
| 10:15 | Inspección de Pozos de Inyección Clase V | |
| | Tipos de inspección<br>Preparativos para una inspección clase V<br>Conducción de la inspección<br>Actividades subsiguientes a la inspección<br>Consejos útiles sobre tipos / inspecciones de pozos clase V | |
| 12:15pm | Almuerzo | |
| 1:15 | Muestreo de Pozos de Inyección Clase V | Felix Román, UPRM |
| | Selección del laboratorio<br>Selección del punto de muestreo<br>Equipo de muestreo<br>Envases de Muestreo<br>Métodos y procedimientos básicos de muestreo<br>Garantía de Calidad / Control de Calidad<br>Obtención de la muestra | |
| 3:00 | Receso | |
| 3:15 | Tipos de muestras y de análisis<br>Documentación y envío de las muestras<br>Modificaciones en el campo<br>Procedimiento estándar de operación de salud y seguridad<br>Plan de salud y seguridad<br>Evento típico de muestreo | |
| 4:00 | Situaciones Hipotéticas de Inspección de Pozos de Inyección Clase V | Jorge Rivera-Santos |
| 5:00 | Cierre del día | |

| Viernes 11 de agosto de 2000 | | |
|---|---|---|
| 8:00am | Preparación para visita de campo (se reúnen en el salón Terraza Adm. Central UPR) | Jorge Rivera Santos |
| 8:30 | Salida visita de campo | |
| | Observación de pozo clase V<br>Demostración de equipo y protocolo de muestreo | |
| 12:00pm | Almuerzo | |
| 1:00 | Discusión y preguntas sobre visita de campo | Jorge Rivera Santos y Felix Román |
| 1:30 | Examen (con manual abierto) | |
| 3:30 | Receso | |
| 3:45 | Corrección y discusión del Examen | |
| 4:45 | Recogido de hojas de evaluación | |
| 5:00 | Cierre del día | |

# Underground Injection Control Program
# Training Course
# Certification of Inspectors

August 9-11, 2000
San Juan, Puerto Rico

Course schedule

| Wednesday, August 9, 2000 | | |
|---|---|---|
| 8:00am | Registration | |
| 8:30 | Welcome | Jorge Rivera-Santos, PRWRERI |
| | EPA's Water Resources Academy | Norma Ortega, EPA |
| | Underground Injection Control Program (UIC) – EPA | |
| | Underground Injection Control Program – Environmental Quality Board | Denise Laabes, EQB |
| | Instructors Introduction<br>Course Objectives | Jorge Rivera-Santos |
| 9:00 | Pre-examination | |
| 10:00 | Coffee Break | |
| 10:15 | Introduction to underground water hydrology and geology of Puerto Rico | José Molinelli, UPR-RP |
| 12:15pm | Lunch | |
| 1:15 | General discussion of UIC program | Jorge Rivera-Santos |
| | Program summary<br>Well classification system<br>UIC program Amendments | |
| 2:00 | UIC inspections | Graciela Ramírez-Toro, CECIA |
| | Summary of the SDWA and its amendments<br>Regulations and authority to conduct inspections under SDWA<br>Inspector's functions<br>Inspector's responsibilities | |
| 3:00 | Coffee break | |
| 3:15 | Facility access | |
| | Regulation considerations<br>Constitutional considerations<br>Case study<br>Facility access denial | |
| 5:00 | Closure | |

| Thursday, August 10, 2000 | | |
|---|---|---|
| 8:00am | Field safety | Jorge Rivera-Santos |
| | Protection gear<br>Other safety measurements | |
| | Mechanical integrity tests | |
| | Well log | |
| | Well closure and abandoned wells | |
| 10:00 | Coffee break | |
| 10:15 | Inspection of Class V Injection Wells | |
| | Types of inspection<br>Preparations for a class V inspections<br>Conducting the inspection<br>Activities following the inspection<br>Advice about types/inspections of class V wells | |
| 12:15pm | Lunch | |
| 1:15 | Sampling Class V Injection Wells | Felix Román, UPRM |
| | Selection of the laboratory<br>Selection of the sampling point<br>Sampling equipment<br>Sampling containers<br>Basic sampling methods and procedures<br>Quality Assurance/Quality Control<br>Obtaining the sample | |
| 3:00 | Coffee break | |
| 3:15 | Types of sampling and analyses<br>Documentation and shipment of the samples<br>Field modifications<br>Standard health and safety operation procedures<br>Health and safety plan<br>Typical sampling event | |
| 4:00 | Hypothetical Situations from the Inspection of Class V Injection Wells | Jorge Rivera-Santos |
| 5:00 | Closure | |

| Friday, August 11, 2000 | | |
|---|---|---|
| 8:00am | Preparations for the filed trip (will meet in room Terraza Adm. Central UPR) | Jorge Rivera Santos |
| 8:30 | Departure for the field trip | |
| | Observation of a class V well<br>Sampling equipment demonstration and protocol procedures | |
| 12:00pm | Lunch | |
| 1:00 | Questions and discussion over the field trip | Jorge Rivera Santos y Felix Román |
| 1:30 | Examination (open-book) | |
| 3:30 | Lunch break | |
| 3:45 | Grading and discussion of the examination | |
| 4:45 | Evaluation sheets taken-up | |
| 5:00 | Closure | |

# Appendix B
# Addendum to the UIC Manual
# (Spanish Version)

Adenda al Manual de Inspección de Control de Inyección Subterránea

## *Nuevos requerimientos reglamentarios para ciertos pozos de inyección subterránea clase V*

Los pozos de inyección clase V son sistemas de disposición pocos profundos los cuales son utilizados para inyectar una variedad de líquidos bajo la superficie del terreno. Los pozos de inyección están regulados por la Agencia de Protección Ambiental (EPA por sus siglas en inglés) y por el Estado (Estados con Autoridad Primaria) mediante el Programa de Control de Inyección Subterránea (CIS) con el propósito de proteger, contra la contaminación, las fuentes subterráneas de agua potable.

Los pozos de inyección clase V son una preocupación porque representan un riesgo de contaminación para las fuentes subterráneas de agua potable. El 85% de los sistemas públicos de agua potable de EEUU utilizan agua subterránea como una fuente de abasto de agua potable.

La EPA estima que existen alrededor de 600,000 pozos de inyección clase V en uso actualmente en los Estados Unidos. Los pozos de inyección clase V están localizados en todos los estado, incluyendo Puerto Rico, especialmente en áreas sin servicio de alcantarillado sanitario donde la población probablemente depende del uso de agua subterránea como su fuente de abasto principal de agua potable. Existen muchos tipos de pozos de inyección clase V, los cuales incluyen pozos para dispones desperdicios líquidos de vehículos de motor, pozos sépticos de gran capacidad, pozos para disponer del drenaje de aguas de escorrentía pluvial, pozos de remediación para acuíferos y sistemas sépticos de gran capacidad. Los líquidos inyectados a través de algunos de estos pozos tienen un gran potencial de contener concentraciones elevadas de contaminantes que ponen en riesgo las fuentes de agua potable.

Los pozos de inyección clase V están al presente reglamentados por el programa de Control de Inyección Subterránea (CIS), bajo la autoridad de la Ley de Agua Potable Segura (LAPS). Bajo la presente reglamentación federal, los pozos de inyección clase V están "autorizados por regla" en la parte 144 del volumen 40 del Código de Registro Federal (40 CRF 144). Esto significa que los pozos de inyección clase V no requieren un permiso si éstos no ponen en peligro las fuentes subterráneas de agua potable y si cumplen con los otros requerimientos del programa de Control de Inyección Subterránea. Los requerimientos de este programa incluyen (1) someter información básica de los pozos de inyección clase V a la EPA o a la agencia del estado con autoridad primaria y (2) construir, operar y cerrar los pozos de inyección clase V en tal manera que proteja las fuentes subterráneas de agua potable. La EPA o la agencia del estado con autoridad primaria puede solicitar información adicional, o requerir un permiso, con el propósito de asegurar que la calidad del agua subterránea está adecuadamente protegida. Además, muchos de los programas CIS de los estados con autoridad primaria tienen prohibiciones adicionales o requerimientos de permisos para ciertos tipos de pozos de inyección clase V.

Los nuevos requerimientos del programa CIS protegen la salud pública y el ambiente mediante la eliminación o reducción de la inyección de desperdicios líquidos de pozos sépticos de gran capacidad y de pozos para desperdicios de vehículos de motor.

### *Pozos sépticos de gran capacidad:*

A partir de abril de 2000 se prohibe en todo el país la construcción de nuevos pozos sépticos de gran capacidad.

Los pozos sépticos de gran capacidad existentes deberán ser eliminados en todo el país para abril de 2005.

### *Pozos para desperdicios líquidos de vehículos de motor.*

A partir de Abril de 2000 se prohiben nuevos pozos en todo el país. Los pozos existentes en áreas reguladas serán sacados gradualmente de operación (ver detalles adelante), pero sus dueños y operadores pueden optar por una excepción y obtener un permiso. Los permisos deben cumplir con unos requisitos mínimos, incluyendo: 1) cumplir con los Niveles Máximos de Contaminantes (NMC) y otros estándares de salud en el punto de inyección, 2) hacer un muestreo de la sustancia inyectada y cienos y 3) implantar mejores prácticas de manejo, tales como reciclaje y minimización de desperdicios.

Los requisitos para los pozos existentes de disposición de desperdicios de vehículos de motor están ligados con el Programa Estatal de Evaluación de Fuentes de Agua. Los estados están realizando evaluaciones de las fuentes de agua según requerido por las enmiendas a la Ley de Agua Potable Segura (LAPS) de 1996. Las enmiendas requieren que los estados establezcan el Programa de Evaluación de Fuentes de Agua, el cual, cuando sea completado deberá 1) delinear las áreas en los estados donde uno o más sistemas de agua potable públicos tienen su fuente de agua, y 2) identificar, hasta donde sea factible, el origen de contaminantes regulados y varios no-regulados dentro del área delineada para determinar la susceptibilidad de los sistemas de agua potable a tales contaminantes.

Los nuevos requerimientos aplicarán también en áreas de protección de aguas subterráneas según identificadas por la evaluación estatal de los sistemas de agua comunales y no-transitorio no-comunales que usan agua subterránea.

Los requisitos también aplican en otras áreas que los estados identifiquen como áreas sensibles de agua subterránea. Estas áreas son críticas para la protección de las fuentes de agua existentes y futuras ya que las condiciones hidrogeológicas permitirían a los contaminantes emigrar hacia las fuentes de agua potable.

Los nuevos requerimientos para los pozos de disposición de desperdicios de vehículos de motor serán introducidos gradualmente en un periodo aproximado de siete años. Los primeros pozos afectados serán aquellos localizados en las áreas de protección de aguas subterráneas.

### *Pozos de disposición de desperdicios de vehículos de motor en áreas de protección de aguas subterráneas*

Los dueños y operadores en áreas de protección de agua subterránea deben cerrar sus pozos u obtener un permiso dentro de un periodo de un año luego de completada la evaluación estatal de las áreas protección de agua subterránea. Los estados podrán conceder una extensión de un año bajo ciertas condiciones.

Los estados deben completar la evaluación de las áreas de protección de agua subterránea para el 1 de enero de 2004. Si no lo hacen pueden ocurrir tres cosas: 1) la regla aplicaría a todo el estado, y los dueños y operadores tendrían hasta el 1 de enero de 2005 para cerrar sus pozos u obtener el permiso, 2) los estados pueden pedir a EPA una extensión de un año para completar sus evaluaciones y 3) los dueños y operadores tendrían un año, a partir de la terminación de la evaluación estatal de las áreas de protección de agua subterránea para cerrar sus pozos u obtener un permiso.

Si los estados obtienen una extensión y no completan su evaluación, la regla aplicaría a todo el estado y los dueños y operadores tendrían hasta el 1 de enero de 2006 para cerrar sus pozos u obtener un permiso.

### *Pozos de disposición de desperdicios de vehículos de motor en otras áreas sensibles de agua subterránea*

Los estados deben designar otras áreas sensibles de agua subterránea para el 1 de enero de 2004. Los dueños y operadores de los pozos existentes en estas áreas sensibles de agua subterránea tienen hasta el 1 de enero de 2007 para cumplir con los requerimientos.

Si los estados no designan las áreas sensibles de agua subterránea para el 1 de enero de 2004, tres cosas pueden ocurrir: 1) la regla aplicaría a todo el estado y los dueños y operadores tendrían hasta el 1 de enero de 2007 para cerrar sus pozos u obtener un permiso, 2) los estados pueden pedir una extensión de un año a EPA para completar la designación y 3) los dueños y operadores en áreas sensibles de agua subterránea designadas tendrían hasta el 1 de enero de 2008 para cerrar sus pozos u obtener un permiso.

Si los estados obtienen una extensión y no completan su designación, la regla aplicaría a todo el estado y los dueños y operadores tendrían hasta el 1 de enero de 2008 para cerrar sus pozos u obtener un permiso.

# Appendix C
# Additional Material Used in the UIC Training Course

1. General Inspection Form (UIC Program, PR Environmental Quality Board)
2. Service Station Inspection Form (UIC Program, PR Environmental Quality Board)
3. Apartment Building Inspection Form (UIC Program, PR Environmental Quality Board)
4. Calibration Sheet – Dissolved Oxygen (Water Sampling Division, PR Environmental Quality Board)
5. Calibration Sheet – Hydrogen Potential (Water Sampling Division, PR Environmental Quality Board)
6. Calibration Sheet – Conductivity and Salinity (Water Sampling Division, PR Environmental Quality Board)
7. Chain of Custody Form (Water Sampling Division, PR Environmental Quality Board)
8. Inspection Notification Form (UIC, EPA, Spanish version)
9. Categories of Class V Injection Wells

# Appendix D

## UIC Inspector Training Course
## Pre – and Final Test
## (Spanish Version)

**This material has been intentionally Suppressed from this report**

# Appendix E
# Enrollment list

| No. | Last Name | Name | Agency |
|---|---|---|---|
| 1 | Avilés Hernández | Ada | DRNA |
| 2 | González | Ada | JCA |
| 3 | Maldonado | Alberto | ADS |
| 4 | Matías | Alberto | Municipio de Aguada |
| 5 | Díaz | Alfredo | JCA |
| 6 | Montalvo | Ana M. | UPR – Adm. Central |
| 7 | Rivera | Angel | JCA |
| 8 | Salgado Torrella | Angel | EPA |
| 9 | Torres | Antolín | ARPE |
| 10 | Rivera | Antonio J. | OMEP |
| 11 | Delgado | Beatriz | JCA |
| 12 | Padilla | Carlos I. | Compañía de Aguas |
| 13 | Rosario Rodríguez | Carmen | ADS |
| 14 | Chaparro | Cesar | Municipio de Aguada |
| 15 | Maldonado | Cristina | EPA |
| 16 | Irizarry | Damarys | NAVY |
| 17 | Barros | Dilsia | Dept. de Agricultura |
| 18 | Ramos | Doris | AAA |
| 19 | García | Edgar W. | NAVY |
| 20 | Reyes | Edwin | JCA |
| 21 | Burgos | Eliud | NAVY |
| 22 | Ramírez | Elliot | DRNA |
| 23 | Lugo Pérez | Elver | ARPE |
| 24 | Irizarry Otaño | Eric A. | UPR - Extensión Agrícola |
| 25 | Rivera Milán | Ethel | AEP |
| 26 | Lugo | Fernando | JCA |
| 27 | Forestier | Florilda | JCA |
| 28 | Hernández | Francisco | UPR – Ponce |
| 29 | Díaz Maldonado | Germán | Compañía de Aguas |
| 30 | Rodríguez | Gisela | JCA |
| 31 | Toro | Gloria | JCA |
| 32 | Lorenzo | Glorimar | JCA |
| 33 | Cherry | Gregory | USGS |
| 34 | Félix | Grissette | Autoridad de Carreteras |
| 35 | Larracuente Santana | Héctor | Dept. de Salud |
| 36 | Pagán García | Héctor | Dept. de Salud |
| 37 | Castro Ruiz | Ismael | JCA |
| 38 | Ríos | Israel | DOP – Municipio de Florida |
| 39 | García | Jaime | ARPE |
| 40 | Rosado | Jaime | DOP – Municipio de Florida |
| 41 | de Jesús | Jancy | JCA |
| 42 | Nieves | Jeffrey | DRNA |

| No. | Last Name | Name | Agency |
|---|---|---|---|
| 43 | Aponte | John P. | EPA |
| 44 | Nina | Jorge | JCA |
| 45 | Ayala | José | ADS |
| 46 | Figueroa | José | JCA |
| 47 | Martínez | José | JCA |
| 48 | Nieves | José | JCA |
| 49 | Pagán | José | JCA |
| 50 | Villafañe | José | JCA |
| 51 | Juárez | Josefina | JCA |
| 52 | Barroso | Juan | JCA |
| 53 | Vega | Juan C. | JCA |
| 54 | Ramos | Juan | JCA |
| 55 | Ruberte | Juan | ARPE |
| 56 | Serrano Vélez | Lilibeth | EPA |
| 57 | Colón Berlingeri | Lisandra | Dept. de Agricultura |
| 58 | Rivera | Lourdes | JCA |
| 59 | Muriel Díaz | Luz A. | JCA |
| 60 | Mojica Gómez | Luz S. | AAA |
| 61 | Hernández Santos | Lymari | JCA |
| 62 | Espinosa | María E. | ADS |
| 63 | Figueroa | María del C. | JCA |
| 64 | Rivera Marrero | María | JCA |
| 65 | Sánchez | María | Compañía de Aguas |
| 66 | De León Torres | Maridali | Dept. Salud |
| 67 | Ayala | Marta V. | Dept. de Agricultura |
| 68 | Ortiz Mercado | Augusto | Compañía de Aguas |
| 69 | Medina | Migdalia | Municipio de Caguas |
| 70 | Claudio Santiago | Miguel | AEE |
| 71 | Orama | Myrna | JCA |
| 72 | García | Nancy | JCA |
| 73 | Zengotita | Nelson | OMEP |
| 74 | Burgos | Nicolás | Compañía de Aguas |
| 75 | Irizarry | Nimia E. | UPR - Adm Central |
| 76 | Ruiz | Noemí | JCA |
| 77 | Garrafa | Norma | JCA |
| 78 | Nieves Méndez | Norma | Dept. de la Vivienda |
| 79 | Delgado | Oneida | JCA |
| 80 | Martínez Cintrón | Onil | Compañía de Aguas |
| 81 | Laguna García | Paulino | DRNA |
| 82 | Benítez Colón | Rafael A. | AEE |
| 83 | Español Encarnación | Rafael | JCA |
| 84 | Pacheco López | Ramón | JCA |
| 85 | Nuñez Ríos | Raúl | Compañía de Aguas |
| 86 | Torres | René | JCA |
| 87 | Díaz | Rosa del P. | JCA |

| No. | Last Name | Name | Agency |
|---|---|---|---|
| 88 | Pagán Alvarado | Ruth | Dept. de Agricultura |
| 89 | Sánchez | Sandra | JCA |
| 90 | Torres Meléndez | Sandra | ARPE |
| 91 | Cotto | Sonia | Dept. de Agricultura |
| 92 | Medina | Sonimar | JCA |
| 93 | Suárez | Vanessa | JCA |
| 94 | Guzmán Almodóvar | Vivian | ADS |
| 95 | Vega Torres | Vivian | JCA |
| 96 | Guzmán | Xiomara | JCA |
| 97 | Díaz | Yelitza | JCA |
| 98 | Rodríguez | Zuleima | Dept. Salud |
| 99 | Toro | Zulma | JCA |
| 100 | Piñot | Katerina | ARPE |

# Appendix F
# Attendance Register

| Stud. No. | Last Name | Name | Day 1 | Day 2 | Day3 |
|---|---|---|---|---|---|
| 1 | Avilés Hernández | Ada | X | x | x |
| 2 | González | Ada | X | x | x |
| 3 | Maldonado | Alberto | X | x | x |
| 4 | Matías | Alberto | X | x | x |
| 5 | Díaz | Alfredo | X | x | x |
| 6 | Montalvo | Ana M. | X | x | x |
| 7 | Rivera | Angel | X | x | x |
| 8 | Salgado Torrella | Angel | X | x | x |
| 9 | Torres | Antolín | X | x | x |
| 10 | Rivera | Antonio J. | X | x | x |
| 11 | Delgado | Beatriz | X | x | x |
| 12 | Padilla | Carlos I. | X | x | o |
| 13 | Rosario Rodríguez | Carmen | X | x | x |
| 14 | Chaparro | César | X | x | x |
| 15 | Maldonado | Cristina | X | x | x |
| 16 | Irizarry | Damarys | X | x | x |
| 17 | Barros | Dilsia | X | x | x |
| 18 | Ramos | Doris | X | x | x |
| 19 | García | Edgar W. | X | x | x |
| 20 | Reyes | Edwin | X | x | x |
| 21 | Burgos | Eliud | X | x | x |
| 22 | Ramírez | Elliot | X | x | x |
| 23 | Lugo Pérez | Elver | x | x | x |
| 24 | Irizarry Otaño | Eric A. | x | x | x |
| 25 | Rivera Milán | Ethel | x | x | x |
| 26 | Lugo | Fernando | x | x | x |
| 27 | Forestier | Florilda | x | x | x |
| 28 | Hernández | Francisco | x | x | x |
| 29 | Díaz Maldonado | Germán | x | x | x |
| 30 | Rodríguez | Gisela | x | x | x |
| 31 | Toro | Gloria | x | x | x |
| 32 | Lorenzo | Glorimar | x | x | x |
| 33 | Cherry | Gregory | x | x | x |
| 34 | Félix | Grissette | x | x | x |
| 35 | Larracuente Santana | Héctor | x | x | x |
| 36 | Pagán García | Héctor | o | o | o |
| 37 | Castro Ruiz | Ismael | x | x | x |
| 38 | Ríos | Israel | x | x | x |
| 39 | García | Jaime | o | o | o |

| Stud. No. | Last Name | Name | Day 1 | Day 2 | Day3 |
|---|---|---|---|---|---|
| 40 | Rosado | Jaime | x | x | x |
| 41 | de Jesús | Jancy | x | x | x |
| 42 | Nieves | Jeffrey | x | x | x |
| 43 | Aponte | John P. | x | x | o |
| 44 | Nina | Jorge | x | x | x |
| 45 | Ayala | José | x | x | x |
| 46 | Figueroa | José | x | x | x |
| 47 | Martínez | José | x | x | x |
| 48 | Nieves | José | x | x | x |
| 49 | Pagán | José | x | x | x |
| 50 | Villafañe | José | x | x | x |
| 51 | Juárez | Josefina | x | x | x |
| 52 | Barroso | Juan | x | x | x |
| 53 | Vega | Juan C. | x | x | x |
| 54 | Ramos | Juan | x | x | x |
| 55 | Ruberte | Juan | x | x | x |
| 56 | Serrano Vélez | Lilibeth | x | x | x |
| 57 | Colón Berlingeri | Lisandra | x | x | x |
| 58 | Rivera | Lourdes | x | x | x |
| 59 | Muriel Díaz | Luz A. | x | x | x |
| 60 | Mojica Gómez | Luz S. | x | x | x |
| 61 | Hernández Santos | Lymari | x | x | x |
| 62 | Espinosa | María E. | x | x | x |
| 63 | Figueroa | María del C. | x | x | x |
| 64 | Rivera Marrero | María | x | x | x |
| 65 | Sánchez | María | x | x | x |
| 66 | De León Torres | Maridali | x | x | x |
| 67 | Ayala | Marta V. | x | x | x |
| 68 | Ortiz Mercado | Augusto | x | x | x |
| 69 | Medina | Migdalia | x | x | x |
| 70 | Claudio Santiago | Miguel | x | x | x |
| 71 | Orama | Myrna | x | x | x |
| 72 | García | Nancy | x | x | x |
| 73 | Zengotita | Nelson | x | x | x |
| 74 | Burgos | Nicolás | x | x | x |
| 75 | Irizarry | Nimia E. | x | x | x |
| 76 | Ruiz | Noemí | x | x | x |
| 77 | Garrafa | Norma | x | x | x |
| 78 | Nieves Méndez | Norma | x | x | x |
| 79 | Delgado | Oneida | x | x | x |
| 80 | Martínez Cintrón | Onil | x | x | x |
| 81 | Laguna García | Paulino | x | x | x |
| 82 | Benítez Colón | Rafael A. | x | x | x |

| Stud. No. | Last Name | Name | Day 1 | Day 2 | Day3 |
|---|---|---|---|---|---|
| 83 | Español Encarnación | Rafael | x | x | x |
| 84 | Pacheco López | Ramón | x | x | x |
| 85 | Nuñez Ríos | Raúl | x | x | o |
| 86 | Torres | René | x | x | x |
| 87 | Díaz | Rosa del P. | x | x | x |
| 88 | Pagán Alvarado | Ruth | x | x | x |
| 89 | Sánchez | Sandra | x | x | x |
| 90 | Torres Meléndez | Sandra | x | x | x |
| 91 | Cotto | Sonia | x | x | x |
| 92 | Medina | Sonimar | x | x | x |
| 93 | Suárez | Vanessa | x | x | x |
| 94 | Guzmán Almodóvar | Vivian | x | x | x |
| 95 | Vega Torres | Vivian | x | x | x |
| 96 | Guzmán | Xiomara | x | x | x |
| 97 | Díaz | Yelitza | x | x | x |
| 98 | Rodríguez | Zuleima | x | x | x |
| 99 | Toro | Zulma | x | x | x |
| 100 | Piñot | Katerina | o | x | x |

Notes:

x = present
o = not present

# Appendix G
# Final Test Scores

(Passing grade is 60%) Grades have been intentionally removed from table.

| Stud. No. | Last Name | Name | Points | Grade | Remarks |
|---|---|---|---|---|---|
| 26 | Lugo | Fernando | | | |
| 19 | García | Edgar W. | | | |
| 59 | Muriel Díaz | Luz A. | | | |
| 77 | Garrafa | Norma | | | |
| 71 | Orama | Myrna | | | |
| 21 | Burgos | Eliud | | | |
| 34 | Félix | Grissette | | | |
| 16 | Irizarry | Damarys | | | |
| 7 | Rivera | Angel | | | |
| 98 | Rodríguez | Zuleima | | | |
| 8 | Salgado Torrella | Angel | | | |
| 31 | Toro | Gloria | | | |
| 87 | Díaz | Rosa del P. | | | |
| 35 | Larracuente Santana | Héctor | | | |
| 42 | Nieves | Jeffrey | | | |
| 49 | Pagán | José | | | |
| 93 | Suárez | Vanessa | | | |
| 70 | Claudio Santiago | Miguel | | | |
| 66 | De León Torres | Maridali | | | |
| 97 | Díaz | Yelitza | | | |
| 62 | Espinosa | María E. | | | |
| 63 | Figueroa | María del C. | | | |
| 72 | García | Nancy | | | |
| 51 | Juárez | Josefina | | | |
| 32 | Lorenzo | Glorimar | | | |
| 88 | Pagán Alvarado | Ruth | | | |
| 22 | Ramírez | Elliot | | | |
| 58 | Rivera | Lourdes | | | |
| 64 | Rivera Marrero | María | | | |
| 99 | Toro | Zulma | | | |
| 1 | Avilés Hernández | Ada | | | |
| 52 | Barroso | Juan | | | |
| 27 | Forestier | Florilda | | | |
| 28 | Hernández | Francisco | | | |
| 23 | Lugo Pérez | Elver | | | |
| 3 | Maldonado | Alberto | | | |
| 15 | Maldonado | Cristina | | | |
| 47 | Martínez | José | | | |
| 69 | Medina | Migdalia | | | |
| 65 | Sánchez | María | | | |
| 6 | Montalvo | Ana M. | | | |
| 44 | Nina | Jorge | | | |

| Stud. No. | Last Name | Name | Points | Grade | Remarks |
|---|---|---|---|---|---|
| 76 | Ruiz | Noemí | | | |
| 90 | Torres Meléndez | Sandra | | | |
| 95 | Vega Torres | Vivian | | | |
| 82 | Benítez Colón | Rafael A. | | | |
| 11 | Delgado | Beatriz | | | |
| 29 | Díaz Maldonado | Germán | | | |
| 24 | Irizarry Otaño | Eric A. | | | |
| 92 | Medina | Sonimar | | | |
| 100 | Piñot | Katerina | | | |
| 18 | Ramos | Doris | | | |
| 53 | Vega | Juan C. | | | |
| 79 | Delgado | Oneida | | | |
| 96 | Guzmán | Xiomara | | | |
| 61 | Hernández Santos | Lymari | | | |
| 81 | Laguna García | Paulino | | | |
| 10 | Rivera | Antonio J. | | | |
| 89 | Sánchez | Sandra | | | |
| 50 | Villafañe | José | | | |
| 37 | Castro Ruiz | Ismael | | | |
| 57 | Colón Berlingeri | Lisandra | | | |
| 94 | Guzmán Almodóvar | Vivian | | | |
| 25 | Rivera Milán | Ethel | | | |
| 41 | de Jesús | Jancy | | | |
| 5 | Díaz | Alfredo | | | |
| 4 | Matías | Alberto | | | |
| 67 | Ayala | Marta V. | | | |
| 80 | Martínez Cintrón | Onil | | | |
| 60 | Mojica Gómez | Luz S. | | | |
| 68 | Ortiz Mercado | Augusto | | | |
| 84 | Pacheco López | Ramón | | | |
| 78 | Nieves Méndez | Norma | | | |
| 38 | Ríos | Israel | | | |
| 30 | Rodríguez | Gisela | | | |
| 40 | Rosado | Jaime | | | |
| 73 | Zengotita | Nelson | | | |
| 45 | Ayala | José | | | |
| 91 | Cotto | Sonia | | | |
| 83 | Español Encarnación | Rafael | | | |
| 54 | Ramos | Juan | | | |
| 13 | Rosario Rodríguez | Carmen | | | |
| 2 | González | Ada | | | |
| 55 | Ruberte | Juan | | | |
| 9 | Torres | Antolín | | | |
| 74 | Burgos | Nicolás | | | |
| 14 | Chaparro | César | | | |
| 33 | Cherry | Gregory | | | |
| 56 | Serrano Vélez | Lilibeth | | | |

| Stud. No. | Last Name | Name | Points | Grade | Remarks |
|---|---|---|---|---|---|
| 17 | Barros | Dilsia | | | |
| 48 | Nieves | José | | | |
| 86 | Torres | René | | | |
| 46 | Figueroa | José | | | |
| 20 | Reyes | Edwin | | | |
| 75 | Irizarry | Nimia E. | | | |
| 43 | Aponte | John P. | | | |
| 39 | García | Jaime | | | |
| 85 | Nuñez Ríos | Raúl | | | |
| 12 | Padilla | Carlos I. | | | |
| 36 | Pagán García | Héctor | | | |

Notes:

Passed means that the student ***did get*** more points than the minimum required to approved the exam.

Failed means that the student ***did not get*** more points than the minimum required to approved the exam.

NT means that the student did not take the exam.

# Appendix H
# Results of the Course Evaluation

| | Deficient 1 | 2 | Adequate 3 | 4 | Excellent 5 | Total |
|---|---|---|---|---|---|---|
| 1. The material administered during the course was: | 3 - *3%* | 8 - *9%* | 29 - *32%* | 29 - *32%* | 22 - *24%* | *91* |
| 2. The course content satisfied the learning expectative you had at the beginning of the course: | 0 - *0%* | 10 - *11%* | 31 - *35%* | 25 - *27%* | 25 - *27%* | *91* |
| 3. To your understanding, the intellectual level of the conferences was: | 1 - *1%* | 7 - *7.5%* | 47 - *52%* | 29 - *32%* | 7 - *7.5%* | *91* |
| 4. The hands-on practice time (field visit) was | 11 - *12%* | 14 - *15%* | 45 - *50%* | 13 - *14%* | 8 - *9%* | *91* |
| 5. The physical facilities (classroom, restrooms, etc.) were: | 0 - *0%* | 1 - *1%* | 7 - *7.5%* | 37 - *41%* | 46 - *50.5%* | *91* |
| 6. The quality of the conferences was: | 1 - *1%* | 2 - *2%* | 27 - *30%* | 37 - *41%* | 24 - *26%* | *91* |
| 7. The speed at which the classroom material was covered was: | 1 - *1%* | 8 - *9%* | 47 - *52%* | 25 - *27%* | 10- *11%* | *91* |
| 8. The length of the conferences was: | 3 - *3%* | 4 - *4%* | 27 - *30%* | 40 - *44%* | 17 - *19%* | *91* |
| 9. The audiovisual aids were: | 4 - *4%* | 6 - *7%* | 24 - *26%* | 27 - *30%* | 30 - *33%* | *91* |
| 10. The quality of the meals was: | 0 - *0%* | 1 - *1%* | 12 - *13%* | 21 - *23%* | 57 - *63%* | *91* |
| Overall | 24 - *3%* | 61 - *7%* | 296 - *32%* | 283 - *31%* | 246 - *27%* | *910* |

**Write any suggestions that you would have in order to improve the quality of this course.**

- Visit facilities with multiple wells to differentiate and compare.
- Provide more field experiences.
- The field visit can include more variety (better planning).
- Include a technical inspection in the visit.
- The practice should have been more comprehensive.
- More time in the hands-on part of the field visit.
- A revision of the exam is necessary to eliminate some questions that create doubt.
- Punctuality (too much time between conferences). Punctuality did not exist.
- Better organization. Better coordination between the class time and the field visits.
- Talk more about inspections in PR and the differences between USA and PR.

- Discuss the state rules. Clarify some points in the manual.
- Provide additional information other than the manual (material mentioned in class). More variety of information.
- Better audio in the conferences and the videos and get videos that are up to date.
- More interaction between the students and the teachers. Smaller groups.
- The course should be more extensive. Go deeper into the more technical aspects.
- Offer the course more often.
- Change the focus towards the problems in PR. Provide more specific examples.
- The people who taught the course are well prepared. Some of the lecturers didn't answer the questions of the audience and they didn't show confidence in their voices.
- Provide lunch and materials to take notes.
- Provide a good syllabus of the course.

**Overall, what was your impression of this course?**

- Very important.
- The course is very beneficial.
- Very good.
- Very interactive.
- All right.
- A very interesting and instructive course.
- Excellent.
- A lot of useful things were learned.
- My expectative were fulfilled.
- Necessary, it should be repeated for those who couldn't attend.
- Very educative and constructive, very efficient in teaching what we have to deal with in Puerto Rico daily.
- This course is truly very important because it lights the spark to protect and maintain our resource.
- It didn't reach the expectative that it should have.
- Very good for the professional studies, advance learning, and as a public service.
- A really good learning experience.
- After some changes are made to improve the course, it will be of great use for those interested.

# USGS Summer Intern Program

# Student Support

| Student Support | | | | | |
|---|---|---|---|---|---|
| **Category** | **Section 104 Base Grant** | **Section 104 RCGP Award** | **NIWR-USGS Internship** | **Supplemental Awards** | **Total** |
| **Undergraduate** | 6 | 0 | 0 | 0 | 6 |
| **Masters** | 9 | 0 | 0 | 0 | 9 |
| **Ph.D.** | 0 | 0 | 0 | 0 | 0 |
| **Post-Doc.** | 0 | 0 | 0 | 0 | 0 |
| **Total** | 15 | 0 | 0 | 0 | 15 |

# Notable Awards and Achievements

None

# Publications from Prior Projects

None