Puerto Rico Water Resources Research Institute Annual Technical Report FY 2007

Introduction

The Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) is one of 54 water research centers established throughout the United States and its territories by Act of Congress in 1964 and presently operating under Section 104 of the Water Research and Development Act of 1984 (P.L.98−242). The general objectives of the Puerto Rico Water Resources and Environmental Research Institute are…

(1) to conduct research aimed at resolving local and national water resources problems,

(2) to train scientists and engineers through hands−on participation in research, and

(3) to facilitate the incorporation of research results in the knowledge base of water resources professionals in Puerto Rico and the U.S. as a whole.

To accomplish these objectives, the Institute identifies Puerto Rico's most important water resources research needs, funds the most relevant and meritorious research projects proposed by faculty from island universities, encourages and supports the participation of students in funded projects, and disseminates research results to scientists, engineers, and the general public. Since its creation, the Puerto Rico Water Resources and Environmental Research Institute has sponsored a substantial number of research projects, supported jointly by federal, state, private, and University of Puerto Rico's funds. Through its website, the Institute's work is more widely known to the Puerto Rican community and, at the same time, provides means of information transfer with regard to the reports produced through the institute's research activities.

The PRWRERI is a component of the Research and Development Center of the University of Puerto Rico at Mayaguez. As such, it acts as official liaison of the University of Puerto Rico with industry and government for all water resources research activities. The Institute also functions as a highly recognized advisor to these two sectors on water resources issues. This role translates into multidisciplinary functions and activities that add relevance and impact to the research program the Institute supports. By virtue of the local relevance of its research and the prestige and leadership of the investigators it has supported, the Institute has become the focal point for water−related research in Puerto Rico.

Meetings, seminars, technical reports, and a quarterly newsletter are used by the Institute to keep the water resources community and general public informed about advances in research. Approximately once every two years, the Institute organizes major conferences on water−related research in Puerto Rico and the Caribbean, in collaboration with other technical organizations in the region. All these activities facilitate the translation of the research sponsored by the Institute into practical applications of direct benefit to industry, government, and the general public.

Research Program Introduction

In FY 2007 the PRWRRI submitted 13 research and technical project proposals to federal and state government agencies, municipalities, and private sector. Four were approved for total funds of $324,225. Three were rejected and Five are still pending. The proposals are as follows.

1. Evaluation of bridges subjected to military loadings, $202,354.00 – USCOE (Approved)

2. Perform an Evaluation for Heavy Metal Removal from the Miradero Water Treatment Facility, $18,000.00 − CDM (Approved)

3. Selection of Sediment Transport Functions for the St. Thomas Island Guts, $18,488.00 – University of USVI (Approved)

4. Evaluación de Estudios Hidrológico/Hidráulicos para el Departamento de Recursos Naturales y Ambientales de Puerto Rico DRNA $85,383.00 (Approved)

5. Desarrollo de un Plan Comprensivo de Manejo Integral para la Cuenca Hidrografica del Lago Dos bocas EMPR $179,282.00 (Pending)

6. Evaluación Fisica, Quimica y Mineralogica de los Suelos en las inmediaciones del Manatial de Baños de Coamo y Determinación del Flujo Promedio de las Aguas Termales – Municipio Coamo $31,639.00 (Pending)

7. Hydrodynamic and Salinity Study for Boqueron Wildlife Refuge – DRNA $210,000.00 (Pending)

8. Regional Water Quality Coordination in USEPA $304,000.00 (Pending)

9. AWM – Nutrient Database DRNA $175,000.00 (Pending)

10. Defining the Role of Extended Hypolimnion Anoxia in the Water Quality of Tropical Reservoirs, USGS, $173,120.00 (Rejected)

11. Plan de Muestreo o Seguimiento de Concentración de Gases − Municipio Isabela $16,159.00 (Rejected)

12. Desarrollo de un Modelo Hidraulico Operacional del Sistema de Distribución de Agua Potable para Cabo Rojo− AAA $175,000.00 (Rejected)

During FY 2007 the PRWRRI administered Four projects funded under Section 104B (two new projects, one extended from FY2006, and one extended from FY2005), in addition to other projects funded by other agencies, as per approved proposals. Previous fiscal year continuing projects include

1. Regional Water Quality Coordination project in USEPA Region III, in collaboration with Rutgers University and Cornell University.

2. Comprehensive Integrated Management Plan for the Mayaguez Bay Watershed.

3. Establishment of the Center of Excellence for Water Quality.

A Call for Proposals to the research community of Puerto Rico was issued in October, 2007. Only Three submissions ware received.

Dr. Jorge Rivera−Santos continued to monitor the progress of the research projects and continued to be a liaison between the University of Puerto Rico and other agencies including the Caribbean Office of the US Geological Survey. The director targeted other local government agencies to become directly involved with through the arrangement of Memorandums of Understanding (MOUs).

Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing

Basic Information

Title:	Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing
Project Number:	2005PR20B
Start Date:	3/1/2004
End Date:	12/31/2008
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Nutrients, Nitrate Contamination, Non Point Pollution
Descriptors:	
Principal Investigators:	Fernando Gilbes

Publication

SYNOPSIS

Project Number: 2005PR20B (extended to FY2008)

Start: 03/01/2004
End: 12/31/2008

Title: Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing

Investigators: Gilbes, Fernando

Focus Categories: Nutrients, Nitrate Contamination, Non-Point Pollution

Congressional District: N/A

Descriptors: N/A

Problem and Research Objectives:

Several point and non-point sources pollution have been identified in the San Juan Bay National Estuary (SJBNE) and represent a potential threat to the site in maintaining its environmental balance and protection of the local surviving species. During 1994 and 1995, the United States Geological Survey (USGS), in cooperation with the United States Environmental Protection Agency (EPA), and the Puerto Rico Environmental Quality Board (EQB), conducted water and sediments sampling survey on the SJBNE. While on certain section of the SJBNE the conditions have improved, there are still degraded conditions at the Caño Martin Peña and at the San Jose Lagoon (SJL), the results of the survey reflected presence of toxic sediments deposited in the above surface water systems. Furthermore, anoxic and abiotic conditions persisted at both systems caused by stagnant water conditions with virtually no mixing during daily ocean tides events.

Monitoring of water pollution with satellite imaging could provide important information related to the nutrients loadings along the SJBNES. Remote sensing techniques are appropriate due to the complexity of the reserve's ecosystem particularly because of the larger mangrove population. This study suggests the use of hyperspectral imaging as a nutrients pollution monitoring tool in tropical estuaries. The Hyperion hyperspectral sensor has the capability to define spectral profiles in the visible and near infrared bands where nitrates and total phosphorus are suspected to reflect. Field reflectance validation was performed to correlate the satellite measurements with true nutrients reflected water quality characteristics at the deeper SJL sections, based on field sampling results. Finally, a mathematical algorithm was developed from a separate research to extract nitrates or phosphorus information from the satellite image based on reflectance characteristics. These data were used to determine nitrates and phosphorus concentration in the lagoon waters. A water quality model will be used to validate the spectral results with predicted nutrients concentrations inside the SJL.

METHODOLOGY:

A. Satellite Sensor

The Hyperion Hyperspectral Instrument (HIS), which was developed by the National Aeronautics and Space Administration (NASA) and installed at NASA's EO-1 satellite, provides a high spatial resolution of 30 meters ranging from the ultraviolet to the infrared spectral bands (operating between the 0.4 to 2.5 μm bands). The HIS also has a high spectral resolution as it provides high radiometric accuracy in 224 spectral bands. Such variety in spectral bands is necessary to identify different vegetation species present inside a small area such as the SJBNES, particularly swamp lands (NASA, 2002), distinguish between the bay's bottom bed and brushes, and identify planted areas. Other sensor alternatives, such as Thematic Mapper (installed in the Landsat 7 satellite), have been considered. However, most of the available sensors have much lower spatial and spectral resolutions not useful for the SJBNES study due to the site's small area.

B. Image Processing

The ENVI 4.2 version software, developed by Research Systems, was used to process and classify the SJBNES images used in this study. ENVI provides needed geometric correction, terrain analysis, radar analysis, raster and vector Geographic Information System (GIS) capabilities. The ENVI 4.0 was purchased by the Geology Department at the University of Puerto Rico's Mayagüez Campus (RUM) where a significant amount of the study activities were completed. Several HIS images were purchased to the USGS, with passes taken without presence of clouds.

Three (3) individual images (See Figures 1, 2 and 3) were produced from the San Jose Lagoon by the HIS on different occasions: February 24, May 12 and August 14, 2006. Raw images were radiometrically calibrated and geometrically corrected using different United States Geological Survey's (USGS) Level 1R algorithms.

Figure 1
February 24, 2006

Figure 2
May 12, 2006

Figure 3
August 14, 2006

The first step was performed by the USGS to convert the images from Level 0 (atmospheric spectral raw data) to digital radiance numbers (radiance spectral data). After geometric correction, visible near infrared bands were aligned with the short wave infrared bands. As a result corrections were made to assign a digital number (zero) to 46 spectral bands for which Hyperion receives no spectral signal.

Atmospheric corrections were performed to the above radiance images with the ENVI-Fast Line-of-Sight Atmospheric Analysis of Hyperspectral cubes (FLAASH) atmospheric correction module. The FLAASH software was used to remove the spectral atmospheric transmission and scattered path radiance using the MODTRAN4 radiative transfer algorithm estimating the radiance received by the sensor. The atmospheric corrections were completed following the FLAASH Atmospheric Correction Guide (Morillo, 2005). Figures 4, 5 and 6 show the reflectance images after atmospherically corrected.

Figure 4
February 24, 2006

Figure 5
May 12, 2006

Figure 6
August 14, 2006

All images were georeferenced to UTM (Universal Traverse Mercator) units using a field geographic positioning system receptor. The image georeferencing was completed using the ENVI 4.2 map registration module with ground control points selected at convenient locations within the adjacent San Jose Lagoon area.

1. Field Data Processing

All terrain and water resources data have been obtained from available sources, such as the United States Environmental Protection Agency (USEPA), the United States Geological Survey (USGS), the United States Department of Agriculture's Natural Resource Conservation Service (NRCS), the National Oceanic and Atmospheric Administration (NOAA), the Puerto Rico Department of Environmental and Natural Resources (PRDENR), the Puerto Rico Environmental Quality Board (PREQB), and others. All satellite imaging has been obtained from NASA.

An *in-situ* sampling survey was conducted at approximately 40 (forty) sampling stations defined by a location grid (Figure 7) during the months of February, May, and August, 2006 for the presence of nitrates and total phosphorus for each sampling station. Analyses and results of samples collected in the field were conducted by a private environmental laboratory (Environmental Quality Laboratory, Inc. (EQLab) in accordance with 40 CFR Part 136 (Methods for Chemical Analysis for Water and Wastes, EPA, 1974).

Figure 7
Field Sampling Grid

Nitrate as nitrogen samples were analyzed following EPA Method 353.2 (Nitrate-Nitrite Nitrogen by Colorimetry). Total Phosphorus samples were analyzed following EPA Method 365.3 (Ascorbic Acid). Quality Control/Quality Assurance documentation (chain-of-custody) for all samples was also provided by EQLab.

Field sample results and chain-of-custody records were obtained from EQLab. While the total phosphorus results were measured at different levels within the lagoon the total nitrates resulted in most of the station in below the method's detection limit. Thus, total nitrates concentrations were not pursued as part of this study.

Radiance values were obtained with the use of a GER 1500 spectroradiometer (Figure 8) at each sampling stations per sampling survey. Field remote sensing reflectance was calculated from average radiance values at each sampling station per sampling survey.

Figure 8
GER 1500 Spectroradiometer

C. Water quality samples (QA/QC protocols)

Field nitrates and total phosphorus water quality samples were obtained from the San José lagoon to validate the results from the Hyperion reflectance data. Grab samples for both parameters were collected from the location grid previously defined in accordance with depth restrictions. Due to the high water turbidity the samples were obtained from the surface. Strict Quality Assurance/Quality Control (QA/QC) procedures were followed in accordance with the U.S. Environmental Protection Agency (EPA) established protocols. Samples handling was evidenced with the use of chain-of-custody documentation, which details: sample number, date, time, type, container information, site name, arrival temperature, and delivery receipt signatures. Five-hundred (500) milliliter polyethylene, uncolored bottles were used with sulfuric acid (H_2SO_4) as the preservative with a pH less than 2. Samples were analyzed using methods EPA 353.2 for Nitrate as Nitrogen, and EPA 365.3 for total phosphorus by EQ Lab, a private environmental quality laboratory, in charge of conducting the analyses. All samples were preserved at a temperature not exceeding 4°C inside coolers provided by EQ Lab until delivered to the laboratory facilities.

D. Algorithm Development

The images evaluation activities were concurrently undertaken with *in-situ* sampling of the bay's waters for nitrates or total phosphorus, with locations identified by the mentioned field grid. Such locations were sited at the San José lagoon. Based on the above data, an algorithm for nutrients concentration was defined using total phosphorus as the leading indicator. The field sampling was accomplished to test and validate the developed algorithm. Since the lagoon is excessively polluted with phosphorus, an algorithm was developed to provide total phosphorus concentrations uniformly distributed throughout the lagoon. However, there are certain limitations in the use of total phosphorus as an indicator. Organic phosphorus is one of the leading components in the sediments of an eutrophicated surface water body. While the intent of the algorithm is to develop a nutrients pollution control management tool, it may provide misleading results as excessive organic phosphorus may influence the spectral map final results without necessarily identifying point and non-point pollution sources. In order to overcome such restriction a water quality model will be used to predict overall total phosphorus concentrations throughout the lagoon with corrections accounting for the organic phosphorus content within the sediments. Another disadvantage may be the inability of the sensor to adequately obtain reflectance measurements from the water column, particularly if turbidity conditions prevail during most part of the year. Thus, surface concentrations are only used for purposes of this research. However, and since the algorithm is intended to provide nutrients concentrations from suspected or unknown pollution sources, spectral characteristics of the water column may not be affecting such purposes.

PRINCIPAL FINDINGS AND SIGNIFICANCE:

Both field sampling and imaging data were collected in several stations within the grid of San Jose Lagoon. Total phosphorus concentration was measured for August 8 and November 7, 2005, and for February 24, May 12, and August 14, 2006. The results are shown in Figure 9.

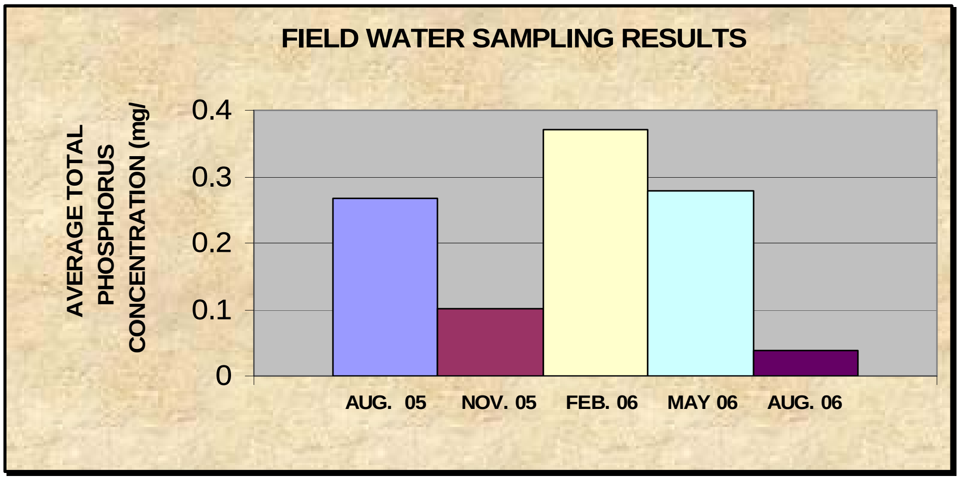


Figure 9: Mean Concentration of Total Phosphorus.

Total phosphorus concentrations at all sampled stations were correlated with the reflectance results obtained from the 2006 geo-referenced Hyperion images. No 2005 images were obtained. Individual bands, bands ratio and logarithmic bands ratio were correlated with total phosphorus concentrations for several surveyed stations. The regression analyses were conducted using the statistical least square method by best fitting the data obtained from both the images and the field. Regression results are shown in Figures 10-14.

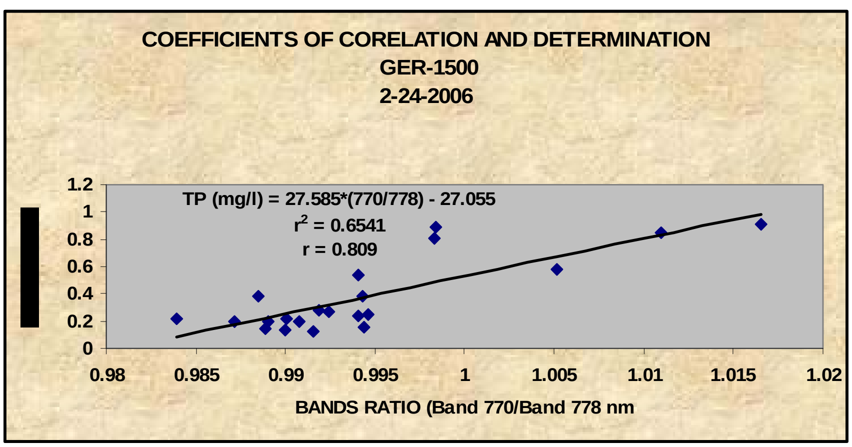


Figure 10
GER-1500 Field Reflectance vs. Total Phosphorus Concentration

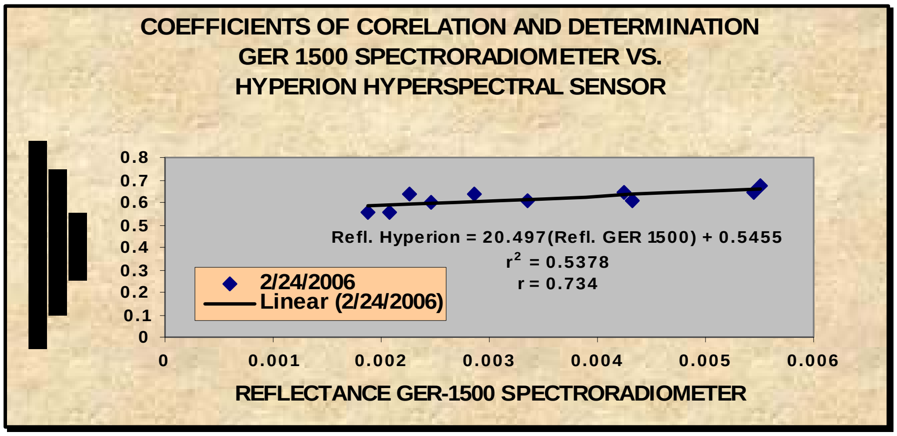


Figure 11
Field vs. Hyperion Images Remote Sensing Reflectance

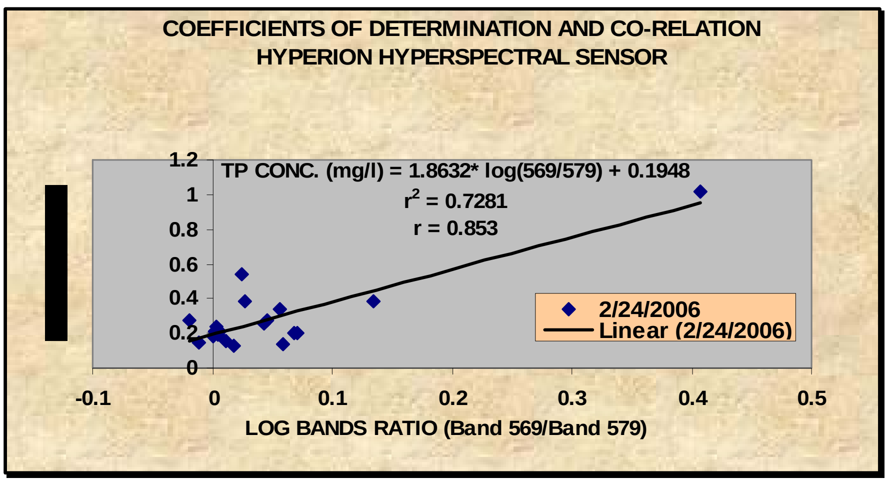


Figure 12
Log Bands Ratio Remote Sensing Reflectance vs. Total Phosphorus Concentration
February 24, 2006

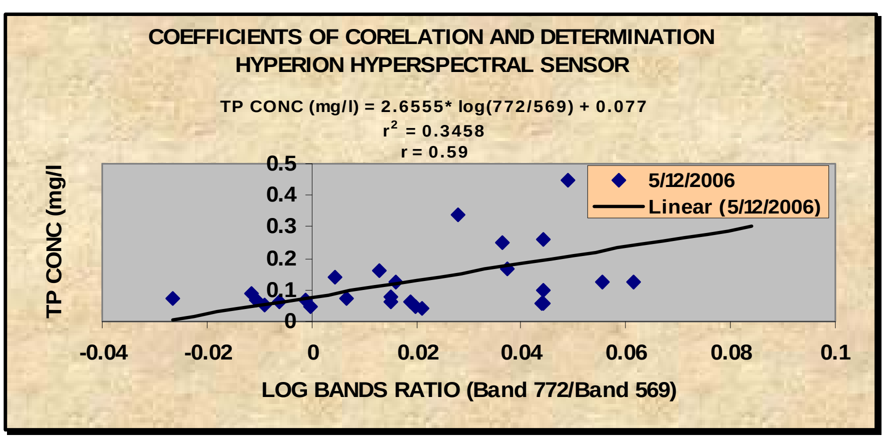


Figure 13
Log Bands Ratio Remote Sensing Reflectance vs. Total Phosphorus Concentration
May 12, 2006

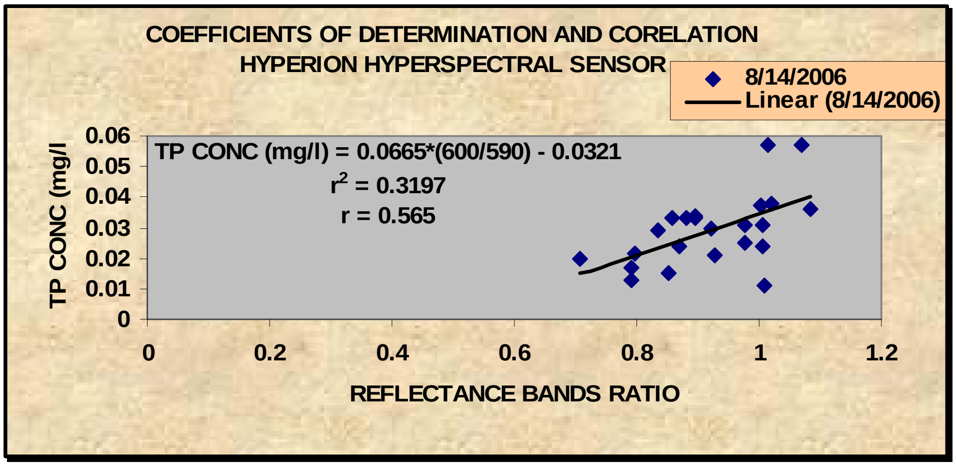


Figure 14
Bands Ratio Remote Sensing Reflectance vs. Total Phosphorus Concentration
August 14, 2006

Based on the performed analyses, the highest correlation corresponded to the log bands ratio vs. total phosphorus concentration for February 24, 2006. That data showed a correlation coefficient of 0.85. The lineal model is defined by the following empirical algorithm:

TP Concentration (mg/l) = 1.8632 * log (Band 569/Band 579) + 0.1948

The reflectance values of the Hyperion image collected during February 24, 2006 were changed to total phosphorus concentration by applying the above algorithm, which resulted in a new image. The resulting image after masked and annotated is shown as Figure 15.

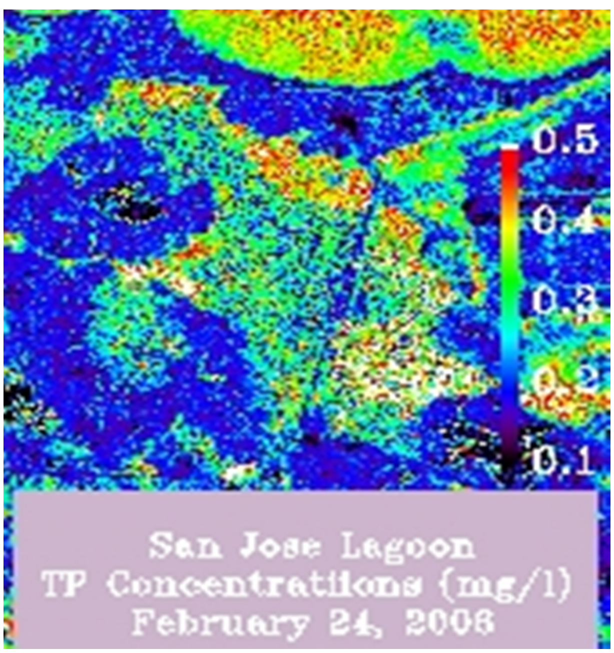


Figure 15
Hyperion Image with Empirical Algorithm

This study demonstrates that hyperspectral remote sensing is an useful tool for the monitoring of total phosphorus distribution in eutrophic lakes and lagoons. The robust correlations estimated for the February 24, 2006 measurements and the weak correlations for the May 12, 2006 and August 14,2006, may suggest that dry season is best suitable for satellite nutrients' monitoring. Since total phosphorus was estimated from reflectance values of the green region of the spectrum, it is necessary to develop additional research to determine the correlation between Chlorophyll and total phosphorus in this eutrophic water system. The obtained results are promising in using hyperspectral sensors for nutrients pollution monitoring. However, such apparatus may not be suitable for the monitoring of water quality parameters in very small system due to its low spatial resolution as compared to sensors with lower spectral resolution.

Finally, this study also demonstrates that the use of hyperspectral remote sensing technology may be an useful, and less expensive tool to establish and implement non-point source pollution control strategies (i.e., Total Maximum Daily Loads, Waste Load Allocations, Assimilative Capacity Studies) in nutrients' polluted surface waters and watersheds.

The results of this research will be used to calibrate a water quality model to predict total phosphorus concentrations within the San Jose Lagoon. Such study is at this time in progress and it is expected to be completed by December, 2008.

PUBLICATIONS

No publications were completed during the year as a result of work funded under Section 104 during the current budget period.

TRAINING ACCOMPLISMENTS

List all students participating in Section 104 projects.

Field of study	Academic Level				Total
	Undergraduate	MS	Ph.D.	Post Ph.D.	
Chemistry					
Engineering:					
Agricultural					
Civil			1		1
Chemistry					
Computer					
Electrical					
Industrial					
Mechanical					
Geology					
Hydrology					
Agronomy					
Biology					
Ecology					
Fisheries, Wildlife, and Forestry					
Computer Science					
Economics					
Geography					
Law					
Resources Planning					
Social Sciences					
Business Administration					
Other (specify)					
Totals			1		1

DISSOLVED OXYGEN DYNAMICS IN TWO RESERVOIRS OF CONTRASTING TROPHIC STATUS IN PUERTO RICO

Basic Information

Title:	DISSOLVED OXYGEN DYNAMICS IN TWO RESERVOIRS OF CONTRASTING TROPHIC STATUS IN PUERTO RICO
Project Number:	2006PR29B
Start Date:	3/1/2006
End Date:	6/30/2007
Funding Source:	104B
Congressional District:	N/A
Research Category:	Water Quality
Focus Category:	Surface Water, Water Quality, Non Point Pollution
Descriptors:	
Principal Investigators:	David R Sotomayor, Martinez Gustavo, Luis R Perez−Alegria, Carlos Santos

Publication

1. Fernando Pantoja, 2007, Dinámica fisicoquímica y fitoplantónica del embalse Guajataca, MS Thesis, Departament of Biology, UPR – Mayaguez, 190 pages.
2. Sotomayor−Ramírez, D. G.A. Martínez, L. Pérez−Alegría 2006. Nutrient management for improved agricultural production and environmental quality. Invited presentation at EXPOCHEM, November 2006. Mayagüez, PR.
3. Sotomayor−Ramírez, D. G.A. Martínez, L. Pérez−Alegría, C. Santos. 2007. Seasonal pattern of dissolved oxygen and stratification in two tropical reservoirs. 30th Congress of the International Association of Theoretical and Applied Limnogy. Montreal Canada, August 12 to 18, 2007. http://www.SIL2007.org/ (projected)
4. Pantoja F., C. Santos, D. Sotomayor−Ramírez, and G.A. Martínez. Physicochemical and planktonic dynamics in a tropical reservoir. 30th Congress of the International Association of Theoretical and Applied Limnogy. Montreal Canada, August 12 to 18, 2007. http://www.SIL2007.org/

SYNOPSIS

Project Number: 2006PR29B (extended to FY2007) Start: 03/01/2005
End: 02/28/2006

Title: Dissolved Oxygen Dynamics in two Reservoirs of Contrasting Trophic Status in Puerto Rico

Investigators: Sotomayor, David R.; Martinez, Gustavo; Perez-Alegria, Luis R.; Santos, Carlos

Focus Categories: Surface Water, Water Quality, Non Point Pollution

Congressional District: N/A

Descriptors: N/A

Problem and Research Objectives:

Low dissolved oxygen (DO) has been identified as the cause of impairment in the principal reservoirs of Puerto Rico (PREQB, 2002). A proper understanding of the DO dynamics in reservoirs cannot be drawn from historical water quality data gathered in reservoirs by public agencies in Puerto Rico because measurements have been rather sporadic in a temporal and spatial scale (3 months apart in the best cases), in very rare occasions have these measurements consisted of depth profiles which could provide some insight as to the factors controlling DO dynamics, and concentrations have not been related to other water quality parameters. The eutrophic conditions due to inputs of sediments and nutrients were identified as the primary reason for the lakes not meeting the water quality standard for DO, yet the waters did not exceed the numeric standards for nutrients (PREQB, 2003). Numerical nutrient reference values for reservoirs of Puerto Rico suggests that the majority exhibit some impact from anthropogenic activities, with six classified in the mesotrophic category, twelve in the eutrophic category and one in the hypereutrophic category (Martínez et al. 2005).

The variations in trophic status across lakes can vary due to non-point source inputs, in-lake geomorphologic characteristics, and circulation patterns due to variations in thermal stability, that will affect DO content and dynamics. Most reservoirs consistently exhibit anoxia at some depth, which causes a significant drop in water column average values. It is unclear whether this is a natural phenomena characteristic of tropical systems or whether is a result of water impairment and thus require remediate actions to be implemented. There is substantial evidence that suggests that tropical reservoirs, even oligotrophic reservoirs, commonly experience temporal hypolimnion anoxia (Townsend, 1996). If this is the case in Puerto Rico, the USEPA criteria of 5 mg DO/L would have to be modified to be more sensitive to natural conditions. There appear to be substantial differences in DO dynamics between tropical reservoirs and temperate systems (Townsend, 1998; Townsend, 1999; Lewis, 2000) which demands a thorough characterization of tropical lake behavior prior to adopting management guidelines developed in temperate areas. The effect of stratification, short-term variations in DO concentrations, as well as the elucidation of natural conditions leading from hypoxic to anoxic conditions must be considered.

This on-going study is characterizing the DO dynamics in two reservoirs as a first step towards the future establishment of DO criteria for Puerto Rico and for providing baseline data for modeling DO dynamics in Puerto Rico. The overall objectives are to assess the limnoligical conditions of selected reservoirs as a means to provide a benchmark to gauge future change and by which to anticipate water quality management. The specific objectives are to:

1) Characterize the circulation and stratification status of two reservoirs, for determination of the degree of hypolimnetic anoxia.
2) Establish cause-effect relationships between causative (temperature, light, nutrients) and DO concentrations in the reservoirs.
3) Relate DO concentrations to variables relating lake productivity, nutrient dynamics, reservoir stratification, and morphometric criteria.

Methodology:

Study sites: Two stations have been established at damsite within Lago Guajataca and Lago Cerrillos (Table 1). Two additional stations were later added which consisted of the transitional zone in Lago Cerrillos and the entrance of Lago Dos Bocas. We have opted to modify the original sampling strategy which was to sample Lago Dos Bocas. We hypothesized that the large sediment loads entering that lake during runoff/storm events would confound interpretation of the data and evaluation of dissolved oxygen dynamics within the water column. Sediment blocks sunlight from reaching deeper depths of the water column thus primary production limitation is due to sediments and not algal biomass within the lake. In addition, the high sediment oxygen demand rates that may be exhibited in that lake may difficult the elucidation of natural mechanisms governing dissolved oxygen dynamics in tropical reservoirs. A preliminary survey of Lago dos bocas will be performed on 26 June 2007.

To date, eleven samplings have been performed in Guajataca and nine samplings have been performed in Cerrillos (Table 2). We expect to study Lago Cerrillos and Guajataca through July 2007, and will be making and will be making sporadic visits to Lago Dos Bocas.

Instrumentation and water quality data collection: Climatic variables for each lake are being gathered from corresponding climatologic stations administered by USGS, which include: mean daily temperature, daily precipitation, wind velocity, reservoir height. Water samples were collected with a 1-L Van Dorn sampler at (i) surface (i.e. approx. 20 cm from the surface), (ii) 1 m depth and (iii) at the extinction coefficient depth (1.7xSD) (Wetzel, 2001), and decanted to acid-washed polyethylene bottles. On 15 and 16 November 2006, sampling was performed within selected depths of Lago Cerrillos and Lago Guajataca, respectively. Samples were transported in ice coolers (<6^{o}C) to the Soil and Water Chemistry Laboratory at the University of Puerto Rico – Mayagüez Campus. A 250 mL portion of the sample was acidified with H_2SO_4 to pH <2 and stored frozen; a second 250 mL portion was filtered through glass-fiber filter for Chlorophyll-a analysis using Turner TD-700 Model fluorometer; and a third 250 mL portion was used for metal analysis or stored frozen in reserve.

Turbidity was quantified in the laboratory with a LaMotte portable turbidity meter. The parameters quantified were: total Kjeldahl nitrogen (TKN) (EPA method 351.2), dissolved nitrate (NO_3) (EPA method 353.1), total phosphorous (TP) (EPA method 365.4), dissolved phosphorus (DP) (365.2) and chlorophyll "a"(EPA method 445.0). Nutrients quantified in dissolved form were filtered through a 0.45 µm membrane. All nutrients were quantified using a BRAN+LUEBBE Ion Auto-Analyzer. Metals were quantified in water samples on selected dates (November profiles) and depths by Univ. of Georgia Soil, Plant and Water Testing Laboratory (http://aesl.ces.uga.edu/).

In situ measurements were pH, electrical conductivity, dissolved oxygen, water temperature, photosynthetically active radiation, and oxidation-reduction potential with a CTD-12 multiparameter probe (Applied Microsystems Inc.; Sidney, BC, Canada). The deployment depth was calculated after correcting the actual pressure for atmospheric pressure using the equation by Wetzel (2001, p. 152). The measured redox potentials were converted to potential in the system relative to standard H_2 electrode (Eh,actual) and corrected for pH and temperature. Electrical conductivity were expressed as that at 25^{o}C (Radtke et al. 1998). Parameters were gathered in 1m intervals to the bottom in descending and ascending manner. All sensors were checked for proper functioning in the laboratory, prior to field sampling and calibrated as needed. Water transparency (Secchi depth) were determined with a 20-cm disk with alternating black and white quadrants in the shaded side of the boat.. Lake depth at the sampling point was determined with a marked tag-line.

The thermocline was determined from the maximum rate of change of temperature with depth and the top and bottom of the metalimnion was determined from the second derivative of the rate of change in temperature at two consecutive depths. The hypolimnetic volume was determined from the bottom of the metalimnion to estimated in-lake median depth. Hypolimnetic volume-weighted dissolved oxygen (VWDO) concentration were calculated from dissolved oxygen concentration and corresponding depth related water volume. The DO per unit area were computed from VWDO, hypolimnion depth and estimated hypolimnion area (Burns, 1995; Pelletier, 1998).

Principal Findings and Significance:

Lake characteristics: Lago Guajataca has a greater drainage and lake area, but lower mean depth than Cerrillos; hence the latter has a greater volumetric capacity (Table 1). We hypothesize that Cerrillos has a greater proportion of anoxic sediment overlain by lake water hypolimnetic volume (hypolimnetic volume / mean anoxic sediment area) than Guajataca. Also, sediment load to Guajataca has historically been greater than in Cerillos. These two indicators suggest that the bottom sediments in Guajataca play a much more important role in recycling nutrients to the water column which could be used by phytoplankton during lake turnover (meromixis or holomixis).

Epilimnetic water quality characteristics: Sechi disk depths ranged from 1.5 to 4.0 m and from 1.8 to 3.0 m in Lago Guajataca and Cerrillos, respectively. Chlorophyll-a values (0 to 1 m) ranged from 2.5 to 5.8 µg/L from August 2006 to February 2007 in Guajataca, after which a large flush in chlorophyll-a values were observed on March

2007 (Figure 1). Values tended to be higher in the entrance than in the damsite of Guajataca. A similar pattern was observed in Cerrillos, but the peak in chlorophyll-a concentration in March 2007 was not as large. The peaks in chlorophyll-a values were coincident with those observed for turbidity (Figure 2), yet in general there was a poor association between chlorophyll-a and turbidity.

Similar nutrient (N and P) concentrations as those quantified by Martínez et al. (2005) were observed during the sampling period for both lakes.

Lake profile water quality characteristics: A depth profile taken on 14 November 2006, in Lago Cerrillos, showed that Chlorophyll-a increased from the surface to 6 m depth and thereafter did not change with depth increase. Profiles taken on February and March 2007, during the expected period of overturn, showed that maximum chlorophyll-a concentrations occurred from the surface to about 8 m, with higher values on the March 2007 sampling. On 16 November 2006, in Lago Guajataca, chlorophyll-a concentrations increased with depth from the surface and peaked at 8 m, thereafter decreasing with depth. On the Febraury sampling in Guajataca, maximum chlorophyll-a concentration was at 1 m. Profile concentrations increased for the March sampling, with maximum values of between 21 and 34 µg/L at between 1 and 4 m depth. A preliminary *in-situ* chlorophyll-a profile taken on 13 December 2006 in Lago Guajataca (E. Otero) revealed that the maximum depth of chlorophyll-a had moved deeper to between 10 and 12 m. In both lakes, turbidity increased with depth with maximum values at about 12 m being 2x surface values (2 NTUs). 10% of the maximum photosynthetically active radiation did not exceed seven meters in both lakes.

In general, water pH increased from the surface to near the metalimnion and then decreased with depth, with values being slightly greater in Guajataca (Figure 3 and Figure 4). This trend is consistent with water quality profile data gathered during November 2006 which showed that Lago Guajataca had greater water hardness (mean of 36.1 vs. 124.1 meq/L for Lago Cerrillos and Guajataca, respectively), Ca, Mg, K, Na, and Si concentrations than Lago Guajataca. Only total Fe and Mn appeared to consistently increase with depth in Lago Guajataca, and did not occur in Lago Cerrillos. Electrical conductivity values generally increased slightly with depth and were generally higher in Lago Guajataca (Figures 3 and 4).

Lago Guajataca was strongly stratified between 6 and 7 months of the year, from April to November. There was a weak stratification for the months of December, February and March (Figure 5). The bottom of the metalimnion ranged from 4.8 to 7.1 from August to December, which in the latter time period evidences the initiation of mixing within the water column (Table 4). Evidence for the formation of the thermocline was again observed on 30 April 2007. The stratification in Lago Cerrillos was not as strong as that in Lago Guajataca, with delta temperature values less than $1^{o}C$ (Figure 6). Stratification was stronger for the months of April to September (approximately 5 months) and weak during October and November. We estimate that there was no stratification from December to March, and were taken as the months of holomixis or meromixis.

The rate of mixing in Lago Guajataca was apparently much slower because by December complete mixing had occurred in Lago Cerrillos, yet in Lago Guajataca it was still on-going (probably due to the fact that Guajataca experienced much higher epilimnion temp and that temperature gradients (epilimnion vs. hypolimnion) were much higher at Guajataca than at Cerrillos).

Dissolved oxygen concentrations generally decreased with depth, at both sites but were always at or above saturation values throughout the epilimnion and the top part of the metalimnion. DO concentrations sharply decreased to less than 10% saturation values in the hypolimnion and in most instances thereafter were effectively zero (< 1 mg/L) (Figures 7 and 8). A similar pattern was observed in Lago Cerrillos except once complete overturn occurred (15 December 2006), concentrations ranged from 87 to 45% throughout the water column to 22 m depth. The oxidation-reduction potential patterned DO patterns during the epilimnion and metalimnion with the redox-cline occurring well below DO minimum (Figures 7 and 8). This is reflective of the presence of alternate redox couples in the absence of oxygen, and further exhaustion of these with increasing depth (Figure 3b and 3d). Volume weighted DO concentrations in Lago Guajataca ranged from 1.3 to 3.8 mg/L, which indicates that the lake does not meet PREQB water quality standards of 5 mg/L. Volume weighted DO concentrations in Cerrillos ranged from 2.6 to 5.9, and was in violation of PREQB standards on selected dates.

Hypolimnetic oxygen content and dynamics: Burns (1995) has shown that estimated hypolimnetic oxygen consumption rates are unrealistically low when DO concentrations fall below 2 mg/L because the DO depletion rates are first order with respect to oxygen concentrations. In Guajataca, 90% of all of the volume-weighted hypolimnetic concentrations measured were below 2 mg/L, so that the computed data may not adequately serve to compare to other lakes, nor to quantitatively show the relationship between oxygen depletion and trophic state of the two lakes evaluated. The hypolimnetic DO concentrations in Guajataca were always less than 1 mg/L. The profile taken on January reveled that DO concentrations persisted to between 1 and 4 mg/L well below the expected thermocline, but concentrations were exhaused by the next sampling date increased in the hypolimnion.

In Cerrillos, a strong oxycline occurred for the months of September to November and in May. At all other times, there were variable hypolimnetic DO concentrations. Hypolimnetic concentrations generally were less than 2 mg/L until November. An increased in hypolimnetic DO concentrations was observed on December and persisted until February after which concentrations were exhaused by the May sampling. Further refinements in DO volumetric contents will be made by obtaining detailed bathymetry data, such that the water volumes corresponding to each of the hypolimnetic depths can be estimated more accurately. Work is also underway to estimate the degree of stratification by quantification of lake water column stability.

References:

Burns, N.M. 1995. Using hypolimnetic dissolved oxygen depletion rates for monitoring lakes. New Zealand Journal of Marine and Freshwater Research. 29: 1-11.

Lewis. 1999. Basis for the protection and management of tropical lakes. Lakes and Reservoirs: Research and management. 5: 35-48.

Martínez, G., D. Sotomayor-Ramírez, and L. Pérez-Alegría. 2005. Development of numeric nutrient criteria in lakes and reservoirs of Puerto Rico, Final Termination Report submitted to PREQB. October 2005.

Ortíz-Zayas, J., F. Quiñones, S. Palacios, A. Vélez, and H. Mas. 2004. Características y condición de los embalses principales en Puerto Rico. Informe en Borrador sometido a ELA-DRNA. Oficina del Plan de Aguas. 180 p. con apéndices.

Pelletier, G. Dissolved oxygen in Lake Whatcom: Trend in the depletion of hypolimnetic oxygen in Basin I from 1983 to 1997. Washington State University Department of Ecology. Ecology Report #98-313. 5 pages with figures, tables and appendices.

PREQB. 20003. Puerto Rico water quality inventory and list of impaired waters. 2002 305(b)/303(d). Integrated Report, Final Version. 160 pp.

Townsend, S. A. 1996. Metalimnetic and hypolimnetic deoxygenation in an Australian tropical reservoir of low trophic status. Perspective in Tropical Limnology, pp. 151-160.

Townsend, S. A. 1999. The seasonal pattern of dissolved oxygen, and hypolimnetic deoxygenation, in two tropical Australian reservoirs. Lakes & Reservoirs: Research and Management. 4: 41 – 53.

Towsend, S.A., 1998. The influence of retention time and wind exposure on stratification and mixing in two tropical Australian reservoirs.

USEPA, 1999. EPA Methods and guidance for analysis of water. USEPA, Wash. D.C. CD-ROM ver. 2.0.

USGS. 2007. USGS Water Data for Puerto Rico. URL: http://nwis.waterdata.usgs.gov/pr/nwis/

Wetzel, R.G. 2001. Limnology. Lake and river ecosystems. Third Edition. Academic Press. San Diego, CA.

Table 1. General characteristics of Lago Guajataca, Lago Cerrillos, and Lago Dos Bocas PREQB. 2003; Ortíz-Zayas et al., 2005; Martínez et al., 2005; Soler-López, 2005; USGS, 2007)

Lake information	Lago Guajataca	Lago Cerrillos	Lago Dos Bocas
Latitude*	18º24’02”	18º04’41”	18º20’06”
Longitude*	66º55’25”	66º24’38”	66º40’05”
USGS Station number	50010800	50113950	50027100
Municipality	Quebradillas, Isabela, San Sebastián	Ponce	Utuado, Arecibo
USGS Hydrologic unit	21010002	21010004	50027100
Drainage area (km2)	63.71	45.33	441.4
Watershed	Rio Guajataca	Rio Bucaná	Rio Grande de Arecibo
Area of lake (km2) to the top of damsite	3.44	2.136	2.579
Maximum depth (m)	27	88	22
Mean depth at damsite (m)	12.4	28	7
Estimated capacity (ac-ft)	33,924	47,258	13,241
Water residence time (yr)	0.4	0.87	0.045
Trophic status as per PREQB (2003)	Mesotrophic	Eutrophic	Mesotrophic
Trophic status as per Martínez et al (2006)	Mesotrophic	Mesotrophic	Eutrophic

* These coordinates are only approximate since the exact GPS location of the sampling points has not been established.

Table 2. Sampling dates corresponding to each lake.

Sampling number	Lago Guajataca	Lago Cerrillos
1	8-Aug-2006	
2	28-Aug-2006	
3	18-Sep-2006	27-Sep-2006
4	16-Oct-2006	18-Oct-2006
5	16Nov-2006	15-Nov-2006
6	13-Dec-2006	15-Dec-2006
7	16-Jan-2007	17-Jan-2007
8	12-Feb-2007	16-Feb-2007
9	12-Mar-2007	16-Mar-2007
10	30-Apr-2007	20-Apr-2007
11	21-May-2007	22-May-2007

Table 3. Temporal variation in overall lake characteriscitcs and hypolimnetic oxygen concentraitons in Lago Guajataca and Lago Cerrillos.

	8-Aug-06	28-Aug-06	18-Sep-06	16-Oct-06	16-Nov-06	13-Dec-06	16-Jan-07	12-Feb-07	12-Mar-07	30-Apr-07	21-May-07
Guajataca											
metalimnion depth (m)											
top	4.9	4.9	5.0	3.7	4.9	7.0				2.8	2.9
bottom	7.1	6.0	5.9	4.8	7.1	8.1				6.1	4.0
width	2.2	1.1	0.9	1.1	2.2	1.1				3.3	1.1
thermocline	7.1	6.0	5.9	4.8	7.1	7.1				3.9	4.0
Hypolimnion depth (m)	19.9	21.0	21.1	22.2	19.9	19.9				23.1	23.0
Hypolimnetic DO (mg/L)	0.4	0.6	0.6	0.9	0.3	0.6				0.0	0.6
Whole lake, volumetric weighted mean (mg/L)	3.8	2.6	2.2	1.9	3.5	3.0	2.4	2.5	1.3	2.2	1.5
Cerrillos			27-Sep-06	18-Oct-06	15-Nov-06	15-Dec-06	17-Jan-07	16-Feb-07	16-Mar-07	20-Apr-07	22-May-07
metalimnion depth (m)											
top			8.1	9.1						6.1	6.7
bottom			10.2	11.2						7.1	8.9
width			2.1	2.1						1.0	2.2
thermocline			10.2	11.2						7.1	7.8
Hypolimnion depth (m)			19.8	18.8						22.9	22.2
Hypolimnetic DO (mg/L)			0.2	0.3	1.8	5.0	5.3	5.1	3.7	3.0	0.1
Whole lake, volumetric weighted mean (mg/L)			2.9	3.0	4.8	5.3	5.9	5.8	5.1	4.5	2.6

Figure 1. Temporal variation in 0 to 1 m chlorophyll-a values and turbidity values in Lago Guajataca (G) and Cerrillos (C). Open symbols correspond to entrance and transitional zones in Guajataca and Cerrillos, respectively and closed symbols corespond to damsite.

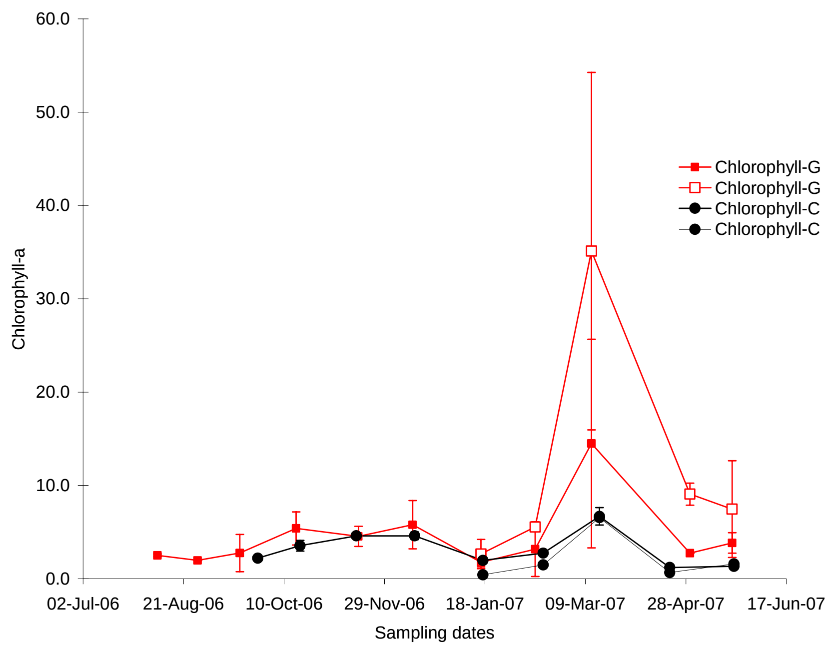


Figure 2. Temporal variation in 0 to 1 m turbidity values and turbidity values in Lago Guajataca (G) and Cerrillos (C). Open symbols correspond to entrance and transitional zones in Guajataca and Cerrillos, respectively and closed symbols corespond to damsite.

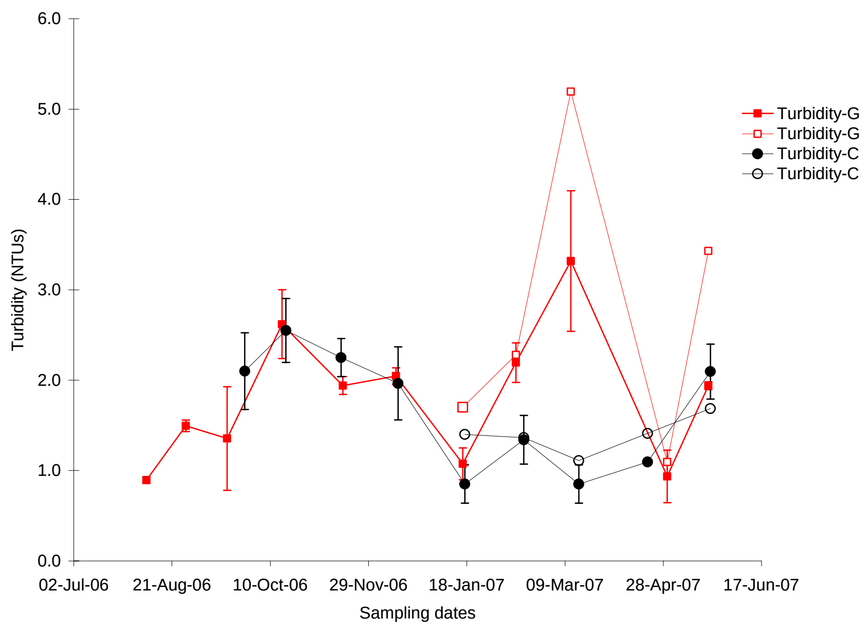


Figure 3. pH and electrical conductivity in Guajataca.

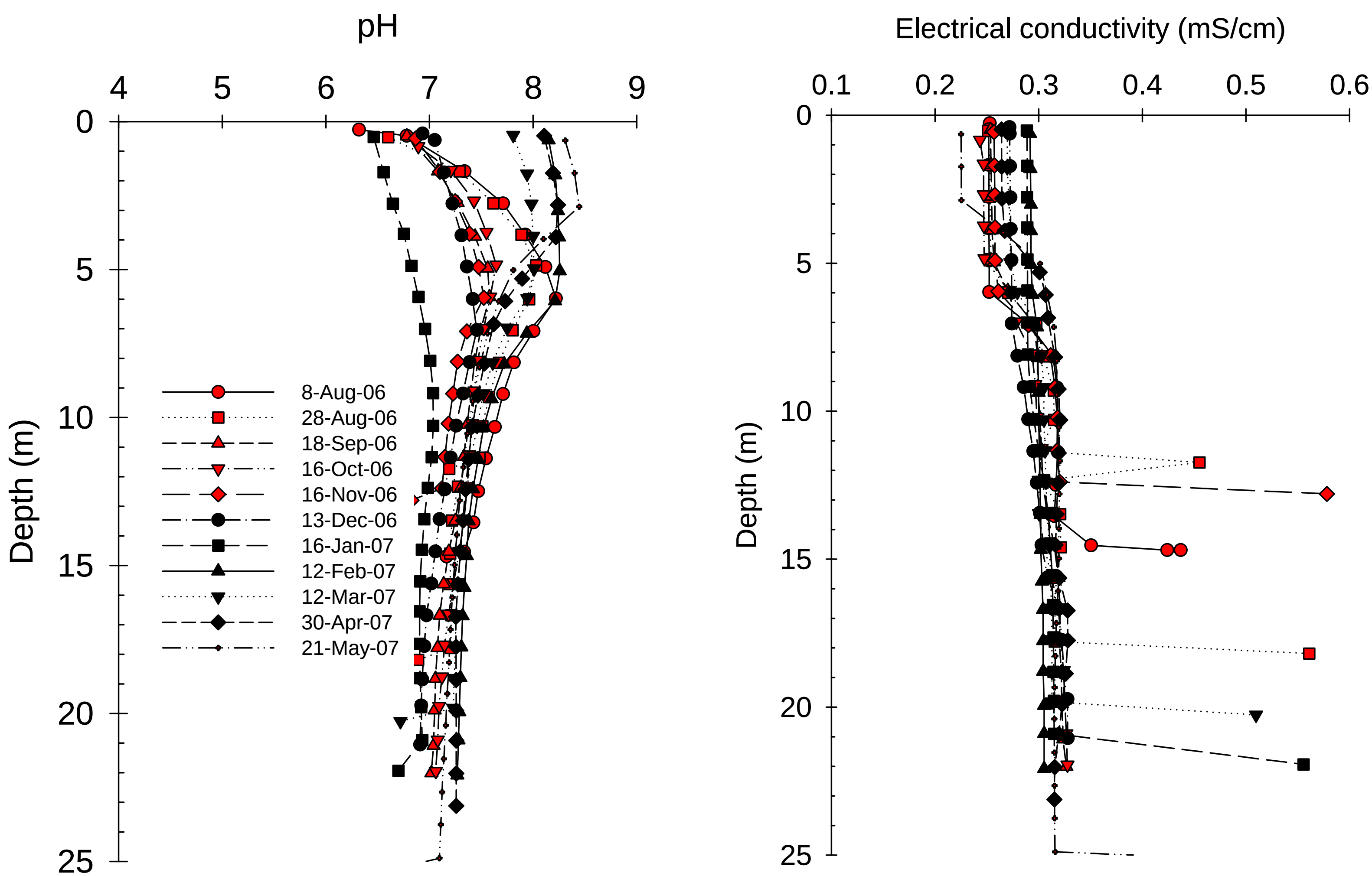


Figure 4. pH and electrical conductivity in Cerrillos.

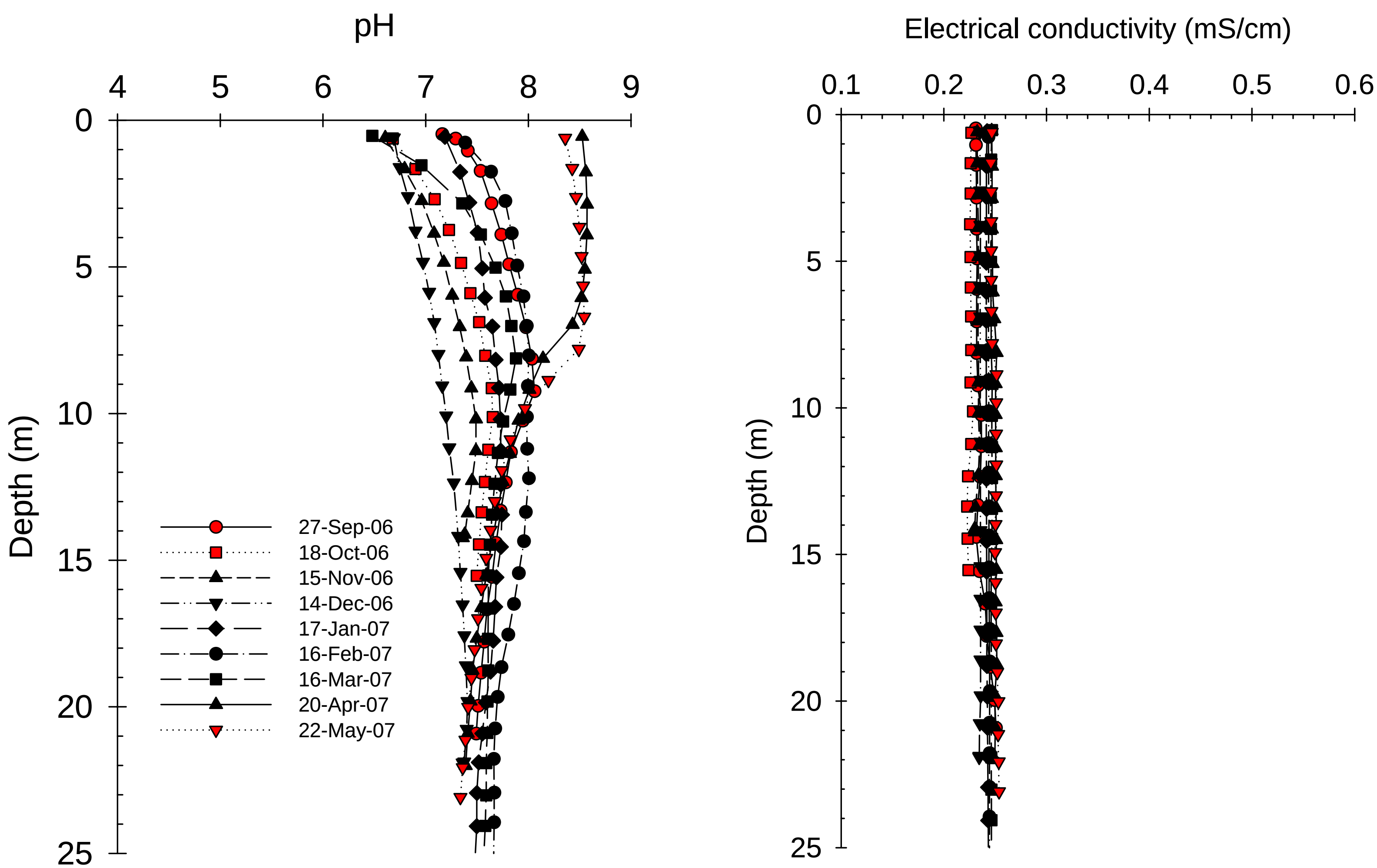
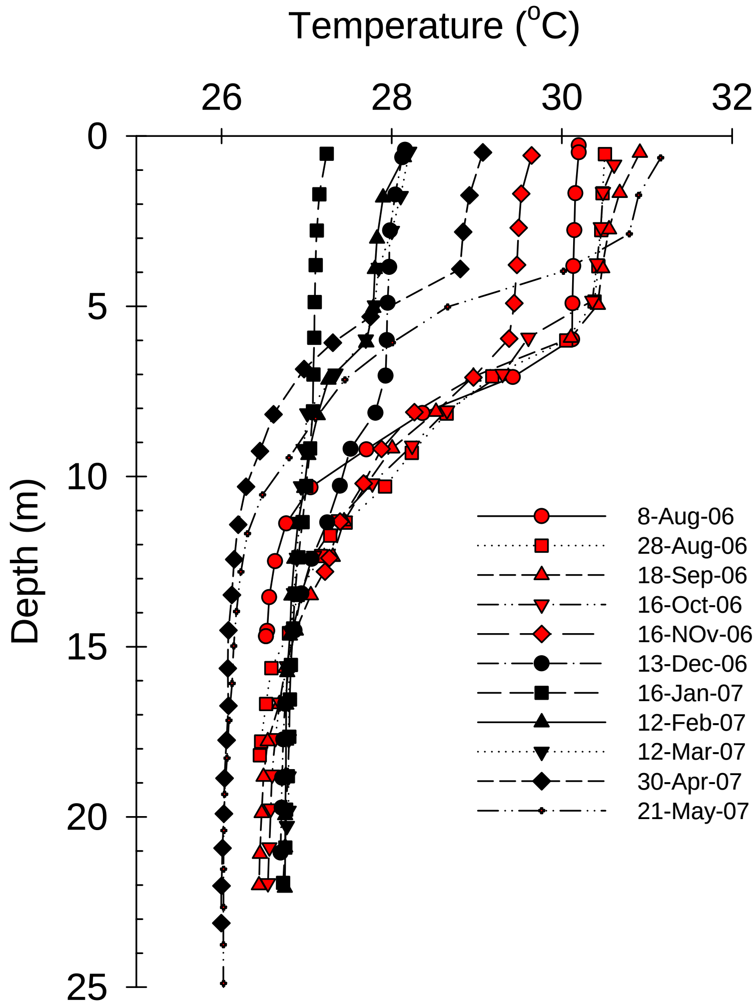


Figure 5. Thermal stratification in Guajataca



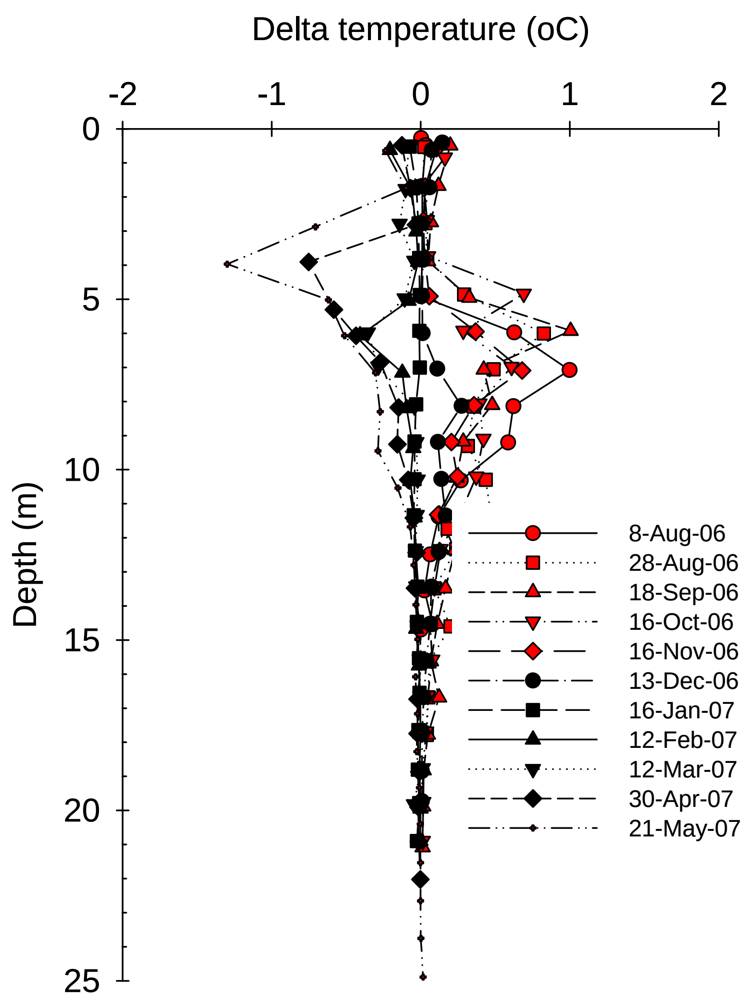


Figure 6. Thermal stratification in Cerrillos

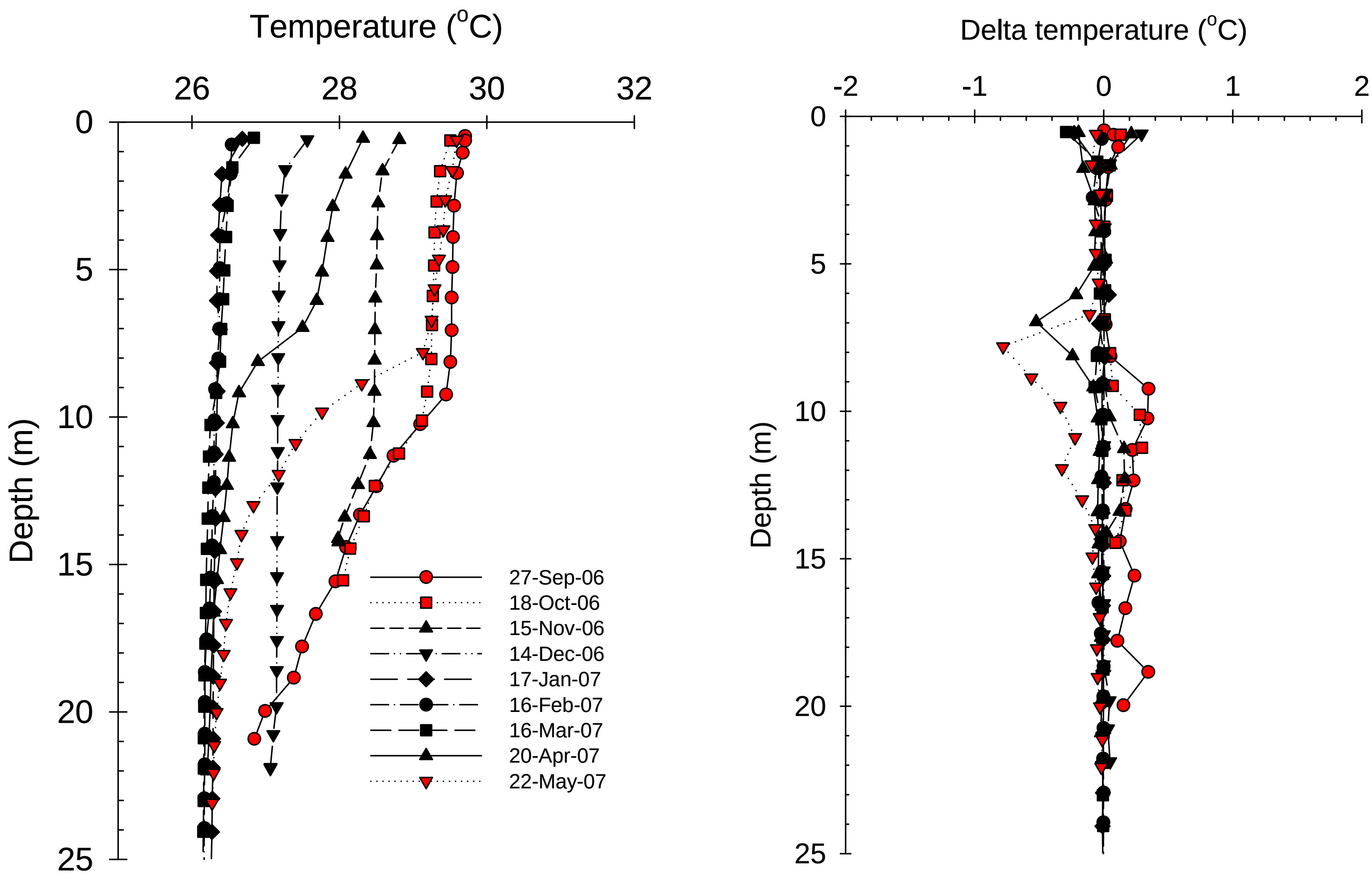


Figure 7. Dissolved oxygen and redox potential in Guajataca.

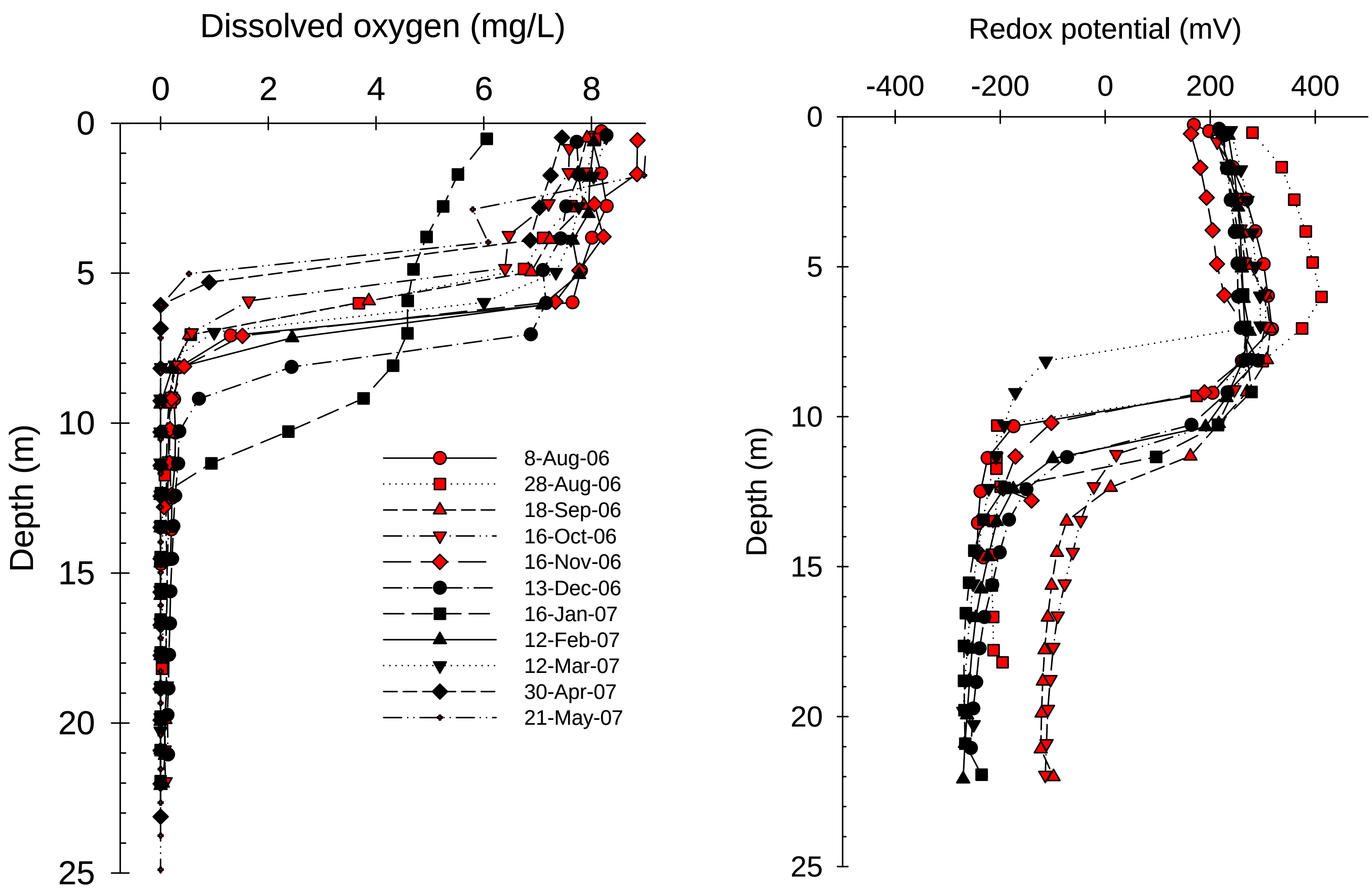
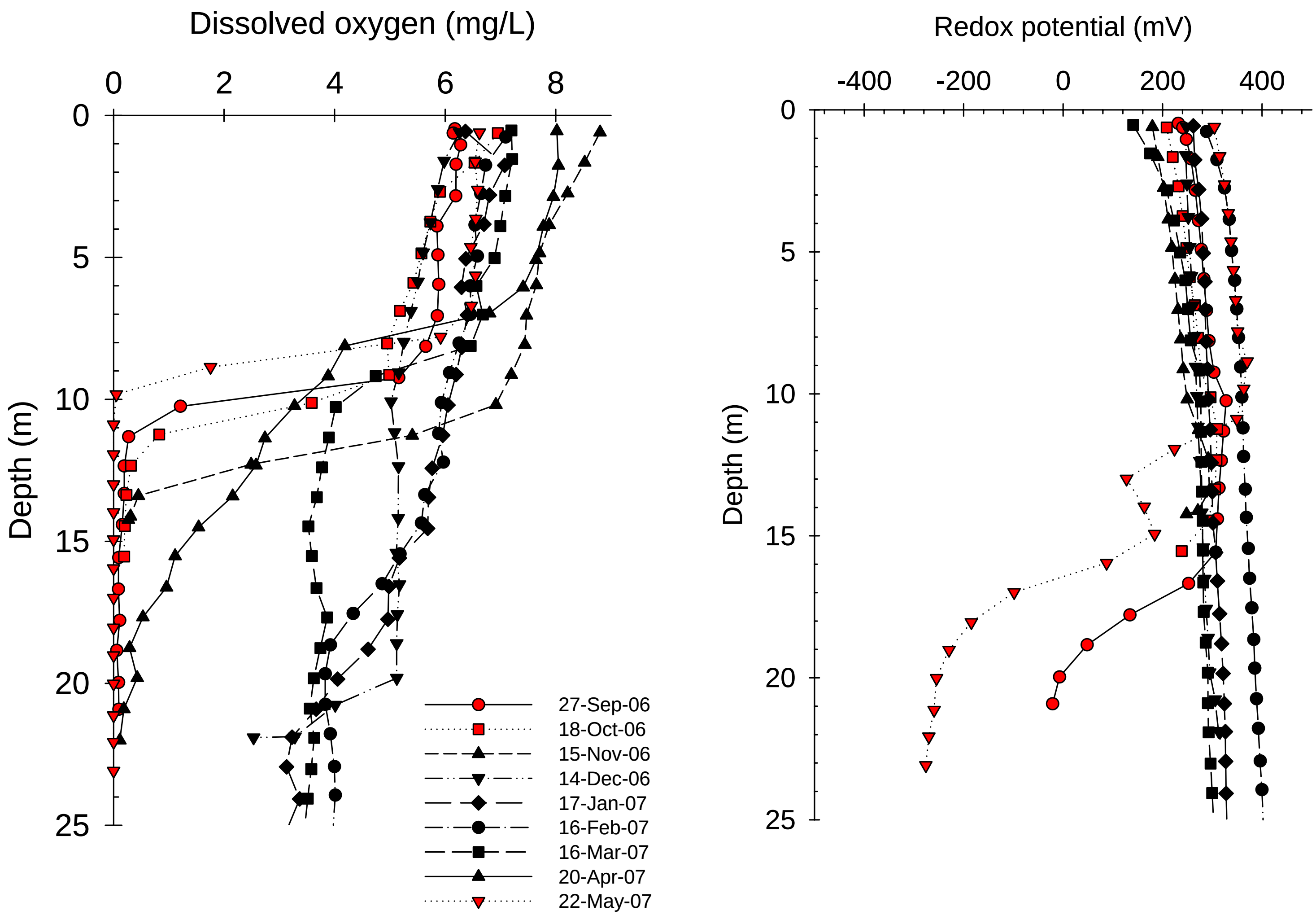


Figure 8. Dissolved oxygen and redox potential in Cerrillos.



Publications

List all publications completed during the year as a result of work funded under Section 104 during the current budget period. Also list publications resulting from Section 104 work completed during previous budget periods if they were not included in a previous report.

1. Articles in refereed Scientific Journals

None

Author (last name, first name)	
Other authors (first name, last name)	
Year	
Title	
Name of Journal	
Volume (number)	
Page numbers	
Supporting Section 104 Project No.	(to be filled by the Institute office)

2. Book Chapters

None

Author (last name, first name)	
Other authors (first name, last name)	
Year	
Title of Chapter	
Name of Editor(s)	
Title of Book	
Publisher	
City	
State	
Page numbers	
Supporting Section 104 Project No.	(to be filled by the Institute office)

3. Dissertations

Author (last name, first name)	Fernando Pantoja
Year	2007
Title	Dinámica fisicoquímica y fitoplantónica del embalse Guajataca
MS or Ph.D. dissertation?	MS
Departament	Biology
College	UPR - Mayaguez
University	
City	
State	
Number of pages	190
Supporting Section 104 Project No.	(to be filled by the Institute office)

4. Water Resources and Environmental Research Institute Reports

Author (last name, first name)	Sotomayor, D.
Other authors (first name, last name)	Martínez, G., and L. Pérez-Alegría
Year	2007
Title	Dissolved oxygen dynamics in two reservoirs of contrasting trophic status
Name of WRERI	
University	UPR-Mayaguez
City	
State	
Number of pages	
Supporting Section 104 Project No.	(to be filled by the Institute office)

5. Conference Proceedings

- Sotomayor-Ramírez, D. G.A. Martínez, L. Pérez-Alegría 2006. Nutrient management for improved agricultural production and environmental quality. Invited presentation at EXPOCHEM, November 2006. Mayagüez, PR.
- Sotomayor-Ramírez, D. G.A. Martínez, L. Pérez-Alegría, C. Santos. 2007. Seasonal pattern of dissolved oxygen and stratification in two tropical reservoirs. 30th Congress of the International Association of Theoretical and Applied Limnogy. Montreal Canada, August 12 to 18, 2007. http://www.SIL2007.org/ (projected)
- Pantoja F., C. Santos, D. Sotomayor-Ramírez, and G.A. Martínez. Physico-chemical and planktonic dynamics in a tropical reservoir. 30th Congress of the International Association of Theoretical and Applied Limnogy. Montreal Canada, August 12 to 18, 2007. http://www.SIL2007.org/

6. Other Publications

None

Author (last name, first name)	
Other authors (first name, last name)	
Year	
Title	
Other information needed to locate publication	
Page numbers (if in publication)	
Number of pages (if monograph)	
Supporting Section 104 Project No.	(to be filled by the Institute office)

TRAINING ACCOMPLISHMENTS

List all students participating in Section 104 projects.

Field of study	Academic Level				Total
	Undergraduate	MS	Ph.D.	Post Ph.D.	
Chemistry					
Engineering:					
Agricultural		1			1
Civil					
Chemistry					
Computer					
Electrical					
Industrial					
Mechanical					
Geology					
Hydrology					
Agronomy					
Biology		2			2
Ecology					
Fisheries, Wildlife, and Forestry					
Computer Science					
Economics					
Geography					
Law					
Resources Planning					
Social Sciences					
Business Administration					
Other (specify)					
Totals					3

‘Waste Tire Crumb Rubber as Sorbent for Heavy Metal Ions: A Field Case−Study’

Basic Information

Title:	‘Waste Tire Crumb Rubber as Sorbent for Heavy Metal Ions: A Field Case−Study’
Project Number:	2007PR35B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Treatment, Toxic Substances, Water Quality
Descriptors:	
Principal Investigators:	OSCAR J PERALES−PEREZ, Felix Roman

Publication

Waste Tire Crumb Rubber as Sorbent for Heavy Metal Ions: A Field Case-Study- Final Report

O. Perales-Perez and F. Roman
University of Puerto Rico at Mayaguez

Abstract

Water pollution by heavy metal species is a major source of environmental concern, and existing technologies are not always adequate for meeting regulatory limits. Major sources of pollution of aqueous effluents with heavy metal ions (mainly Pb, Cu, Zn and Cd) in Puerto Rico are municipal wastewaters treatment plants and the discharges from electroplating, metal finishing and printed circuit board manufacturing industries. Typical concentrations of toxic inorganic species in those aqueous effluents range from 0.1 to 100 ppm. The mercury pollution problem in Juncos and the presence of lead in some wells in Gurabo (Revista Domingo, *El Nuevo Día*, 15 de Junio del 2003), can be considered local case-studies. A local newspaper *Vocero* (August 25, 2004) has also raised concerns on the mercury pollution problem related to its presence in coastal waters in the Vieques area and the consequent bioaccumulation by local fish consumed by the population. In this regard, the presence of Cu, Pb and Zn species in the final discharge generated at the water filtration facility in Mayagüez (as stated by the AAA, the Puerto Rican Agency in charge of potable water facilities) represents an incomparable opportunity to test the capability of crumb rubber to solve an actual environmental problem.

The proposed approach is based on the capability of waste tire crumb rubber (WTCR) to remove hazardous species from aqueous solutions. Our laboratory-scale results have demonstrated the capability of this recycled material to remove inorganic Cu(II), Cd(II) and Pb(II) species from synthetic aqueous solutions. Crumb rubber already cleaned and downsized to different particle sizes, was kindly donated by Rubber Recycling and Manufacturing Corp., REMA, a Puerto Rican company that produces crumb rubber from scrap tires. The sorption property of crumb rubber is attributed to its main components: carbon black, zinc oxide and sulfur, all embedded in an elastomeric matrix.

On the above basis, this proposal addressed the practical evaluation of WTCR to remove Cd, Zn and Pb species from water as reported in the final discharge generated at the Mayagüez water filtration plant. The methodology was focused on the evaluation of waste tire crumb rubber alone or in combination with various potential sorbents available at the water filtration plant location (sludge from sedimentation units). Sludges were samples at the AAA-Mayaguez Facility and characterized. Both, WTCR and dried sludges were capable of removing Cu, Cd and Pb species although under different pH conditions. It was found that WTCR can remove more efficiently and at a faster rate Cu and Pb whereas the dried sludge can easily adsorb Cd. Following the suggestion from the engineers at the facility, the use of Na-thrithiocarbonate (NATC), as chemical precipitant of the contaminants, was also evaluated. Our results suggest the capability of removing Cd, Pb and Cu species by using combined schemes including WTCR and sludge and/or NATC.

1. The Water Filtration Facility at Mayagüez and the final discharge to 'Quebrada Pitillos'.

This water treatment facility is located in Miradero, Mayagüez. The facility, which is fed by Grande and Cañas rivers both in Mayagüez, provides high-quality drinkable water to most of Mayagüez and Añasco locations and only certain areas in Cabo Rojo and Hormigueros. As figures 1 and 2 shows, the facility consists of the following sections: chlorine treatment, coagulation-flocculation, sedimentation, filtration and sludge dewatering. The influent is treated with an aluminum chlorhydrate solution (GC-850, *Gulbrandsen Tech.*) that acts as a primary coagulant and gaseous chlorine before entering the flocculation-sedimentation section. The supernatant (over flow) solution passes through bed-type filters (anthracite and sand beds), chlorinated and finally distributed to recipient populations (point 'A' in figure 1). The solids suspension ('B' in figure 1) generated in the bed-type filtering and settling stages are sent to the sludge treatment section consisting of two gravity thickeners working in series and a pound for sludge dewatering prior its final disposal. The sludge generated in the first gravity thickener is pumped to the dewatering section whereas the corresponding overflow is pumped to the second gravity thickener after addition of an aqueous solution of cationic flocculant G-Floc 2123 (*Gulbrandsen* Tech.) to promote the flocs densification. The overflow from this second thickener, so-called 'final discharge' (point 'C' in figure 2), is finally evacuated to *Quebrada Pitillos*. According to the discharge monitoring report (Table 1), this final discharge reports concentrations of Cu, Pb and Zn above the levels established in the discharge license (NPDES) granted by EPA. These metals can not be removed out from the discharge by using the methods used in the facility.

Table 1. Average concentrations of heavy metal ions in the 'final discharge' (1998-now)

Metal	Average concentration (μg/l)	NPDES standards (2003), μg/l
Cu	155.3	8.0
Pb	21.5	1.8
Zn	108.5	50.0

Source: Discharge monitoring report, AAA-Mayagüez water treatment facility

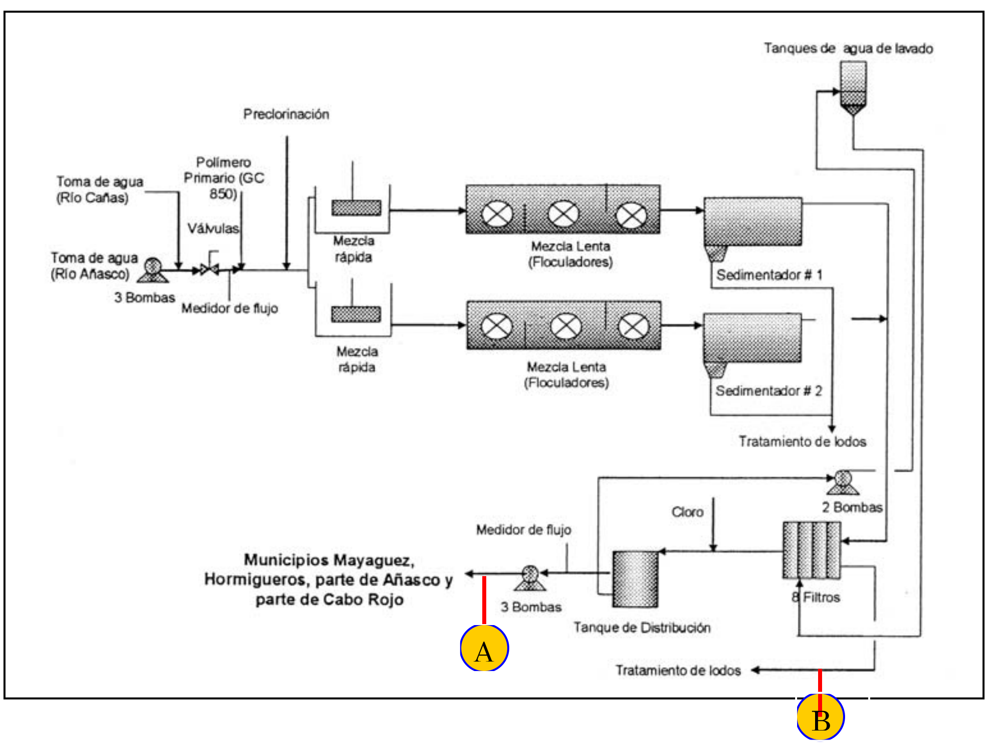


Figure 1. Flow sheet of the Mayagüez-water treatment facility.

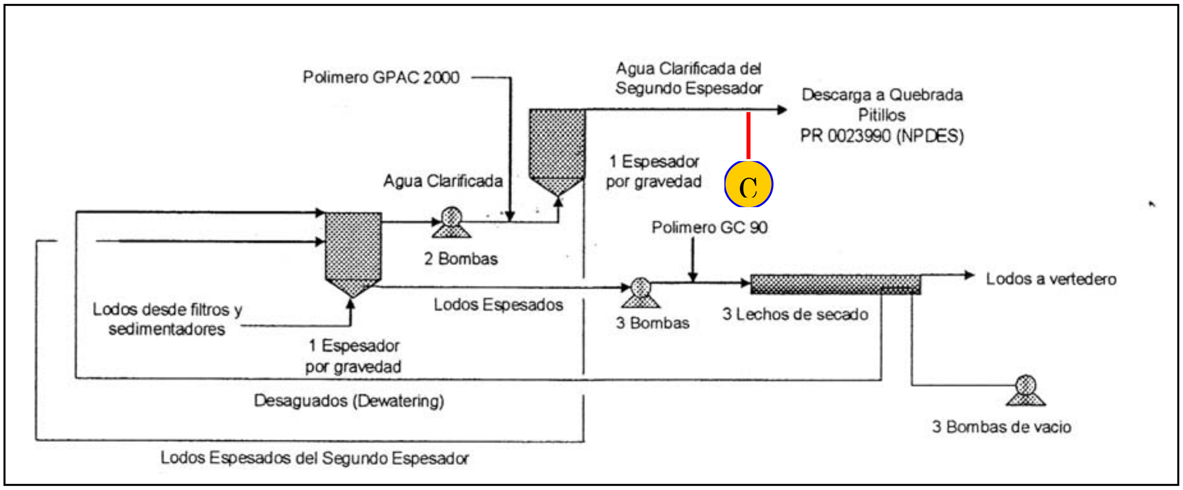


Figure 2. Flow sheet of the thickening and sludge dewatering sections.

2. Methods and Procedures

Granular crumb rubber, screened at different mesh sizes, was provided by REMA Corp. a tire rubber recycling company located in Caguas, Puerto Rico. On the other hand, the AAA provided support to access the water treatment installations to get samples of dewatered sludges, used in the present study.

Figure 3. Crum Rubber manufactured by REMA Inc., Puerto Rico, are big enough to get packed in columns for a continuous cleaning operation.

2.1 Chemical stability of granular crumb rubber

One gram of WTCR at a particular mesh (mesh 30) was contacted with distilled water at the same pH as the actual sample from the final discharge effluents (pH 6-8). The contact time was 24 hours at room temperature conditions. After contact, aliquots were withdrawn, passed trough a membrane filter and analyzed by ICP to determine the release of any inorganic species out from the crumb rubber. These simple experiments will provide important information regarding the chemical stability of the sorbent material before contacting it with actual samples of the final discharge.

2.2 Sorption tests

The following parameters were evaluated in batch equilibrium sorption experiments: concentration of hazardous species, pH, sorbent concentration. All experiments were carried out at room-temperature conditions to reflect real operation conditions. Synthetic solutions bearing Cu, Pb and Zn species were prepared in distilled water at the same concentrations (highest and lowest levels) reported in the AAA-Discharge Monitoring Report (1998-2006). The solution pH will be the same as the value measured in actual final discharge samples. Whenever needed, pH will be adjusted by suitable amounts of NaOH or HNO_3. Prepared multi-ionic solutions were then contacted with granular crumb rubber in Erlenmeyer flasks immersed in a temperature-controlled water bath shaker and mechanical stirrers. After determining the pH of the solutions at the end of the contact period, the samples were filtered trough membrane filters and submitted for quantitative analyses by ICP-MS techniques. In the kinetic experiments, aliquots were obtained at different time intervals and submitted for quantitative analyses of the residual species contents right after filtration. The results of the experimental work will permit to determine the equilibrium uptake, sorption rates, and removal efficiency.
Dried sludge at a concentration of 10-20 g per liter of solution, were placed in contact with 100 mL of 100 or 200 ppb of Cu, Pb, or Zn solutions. Previous studies shows a better uptake at pH 8.0, and we used as guide. Each sample was run by duplicate. Aliquots were taken at different contact times, acidified with nitric acid trace metal grade and later subjected to ICP-MS analysis.
Due to the orientation of the experimental work towards the evaluation of dewatered sludges and the chemical precipitant (NATC), the present report was focused on the evaluation of the various sorption schemes using synthetic solutions. AAA will consider the verification of our results using actual solutions in a forthcoming stage.

2.3 Chemical Precipitation with Sodium Trithiocarbonate (NATC)

According to the manufacturer suggestion, 10ppm of sodium trithiocarbonate was used for each ppm of metal present in solution. A solution containing 1 ppm of each Cu, Pb, and Zn was used in these experiments. Also 250 ppm of GC-850 (aluminun clorohydrate) was added to promote coagulation of produced solids. All the experiments were carried out at pH 8.0.

2.4 Characterization techniques

Inductive Coupled Plasma-Mass Spectroscopy (ICP-MS) was used in this project for the quantitative evaluation of the sorption and desorption experiments. ICP-MS has multi-elemental capabilities, good sensitivity, high precision, accuracy, wide dynamic range and cost effectiveness. US EPA method 200.9 is an ICP-MS method used for the determination of heavy metals including Cu, Pb and Zn in aqueous solutions. Dewatered sludges were sampled, dried and characterized by scanning electron microscope and x-ray diffraction techniques. The elemental analysis of the sludge was also carried out after dissolving it in acid solution.

3. Results and Discussion

3.1 Chemical stability of crumb rubber

As shown in our earlier reports, negligible release of toxic metals, such as lead or cadmium, was observed at pH 6.0 (typical pH value in surface and ground waters). In all cases, the concentrations are below EPA regulations for drinking water. Although Zn ions were released from the ZnO contents in crumb rubber, the concentrations were not above the accepted levels.

Table 2. Concentration of metals released (mg/L) at different pH values. EPA regulations are for drinking water.

	Solution pH				
	1.5	**3**	**6**	**9**	**EPA regulation (mg/L)**
Cu	0.0828	0.0434	ND	0.0001	1.3
Cd	0.0023	ND	0.0010	ND	0.005
As	0.0372	ND	ND	ND	0.050
Zn	2.3842	1.1116	0.4080	0.2924	5
Pb	ND	ND	ND	ND	0
Cr	0.0518	0.0915	ND	ND	0.1

ND. Not detected

3.2 Sludge characterization

<u>SEM analyses</u>

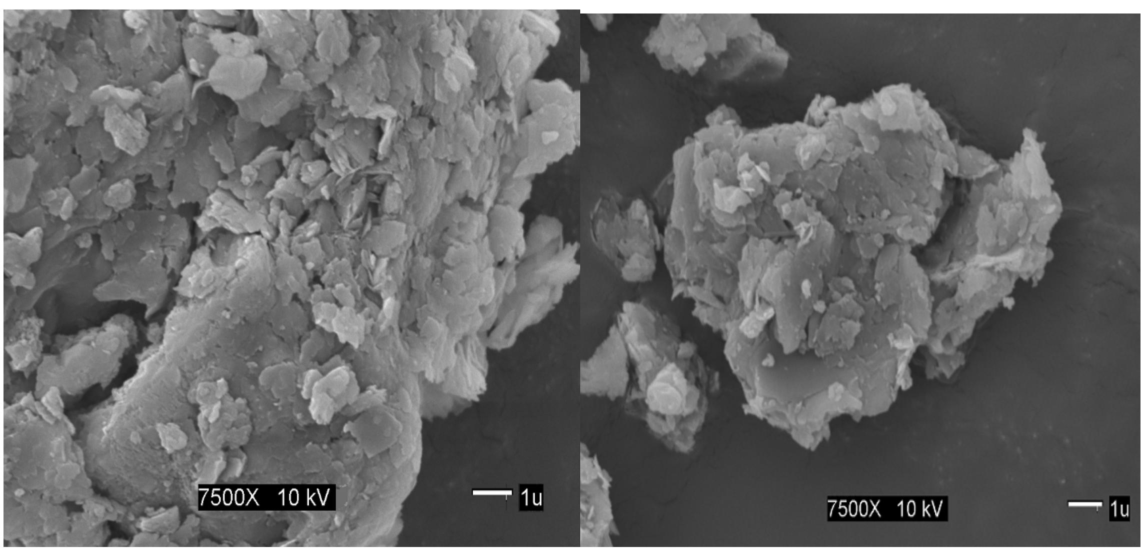


Figure 4. SEM images of dewatered sludges produced at the AAA-Miradero Facility. As observed, the solids consist of aggregated colloids. Colloidal particles are below 1 micrometer in size.

XRD analysis

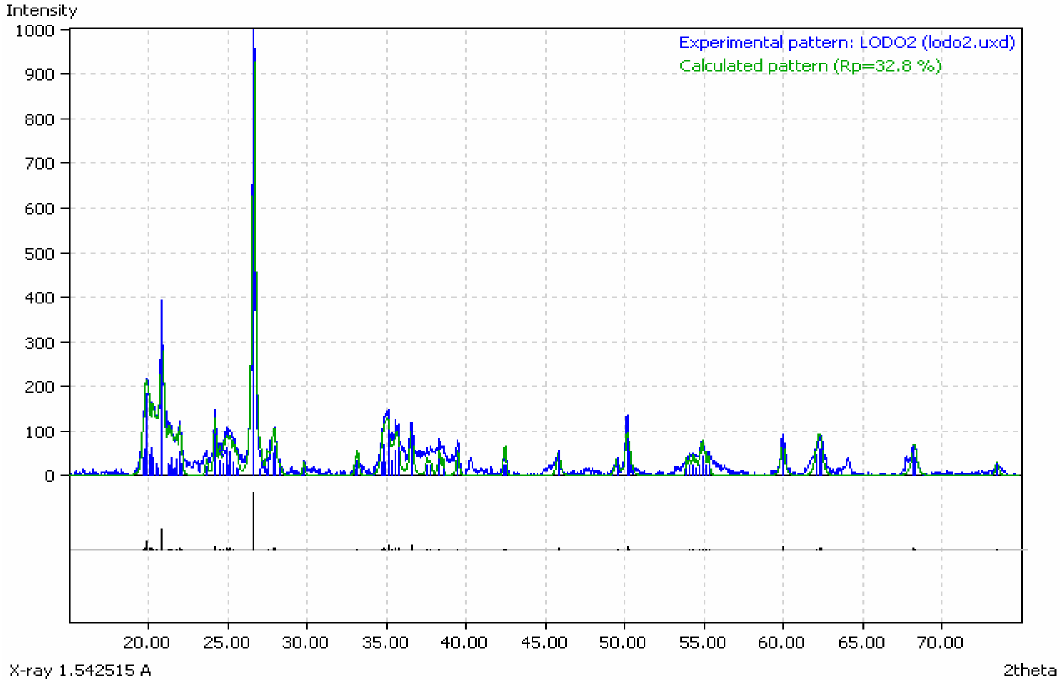


Figure 5 XRD spectrum of dewatered sludge produced at the AAA-Miradero Facility.

The XRD analysis of the powders revealed the presence of silica (SiO_2) as major component. Other components in a crystalline phase are:

- $AlFeO_3$ Aluminum Iron Oxide
- Al_2SiO_5 (Sillimanite)
- Fe_2O_3 (Hematite)
- FeO(OH) (Goethite)
- MgP_4O_{11} Magnesium Phosphate
- $CaCuV_2O_7$ Calcium Copper Vanadium Oxide

Elemental Analysis

The ICP-MS elemental analysis revealed a high content of Fe, Al, Ca, and Mg. Other minor metallic components are: Zn, V, Cu, Cr, and Pb. Showing that the interest metals are in the matrix of the sludge.

Leachability tests (TCLP):

Metal	Metal Content (mg/kg)	Mobilized Metal (mg/kg)	% Metals Mobilization
Cu	19.62	0.90	4.6
Zn	16.19	8.04	49.6
Pb	8.26	0.32	3.8
V	28.39	0.0	0.0
Co	3.2	3.2	100.0

The dewatered sludges would release Zn species back into solution under extreme conditions (acidic environment), which is not usual in water treatment facilities (pH 6-9). The percent of mobilization for lead and copper is below the 5%. Accordingly, under normal operational conditions in the water treatment facility, the release of toxic species from the sludge can be ruled out.

3.3 Sorption tests: Dewatered sludges

The sorption behavior of Zn ions in presence of the dewatered sludge can be summarized by the figure 6. As seen, the sorption level of Zn ions was dependent on its initial concentration. The higher removal efficiency (90%) was achieved for a initial Zn concentration of 200ppb. Evidently, the dewatered sludges can be considered a suitable, and free, sorbent for Zn species in water.

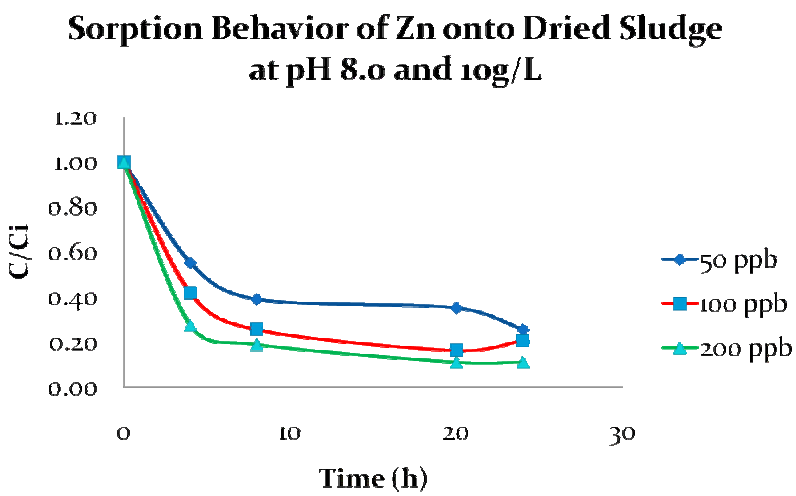


Figure 6. Sorption of Zn ions by dewatered sludged at pH 8. The concentration of the sorbent was 10 g/L

Table 3. Pb, Cu and Zn removal by dewatered sludge

Initial Concentration (ppb)	Pb % Removal	Cu % Removal	Zn % Removal
50	67	82	74
100	67	79	79
200	71	79	89

The sorption behavior of the dewatered sludges was expected because of the major presence of SiO_2 in the sludge (see XRD data), which is an oxide with well-known adsorption capability.

3.3 Sorption tests: WTCR

As an example of typical results, the following figure shows the variation in Cu concentration with time when 175ppb Cu solutions were contacted with WTCR at mesh 30 (diameter <0.67mm) and 14-20 (diameter 1.5-4.0mm). The Cu concentration was selected taking into account the Cu concentration reported in the final effluent of the AAA-Miradero Facility. The sorption pH was 6.0 in these experiments. This optimum pH value was determined from our earlier works.

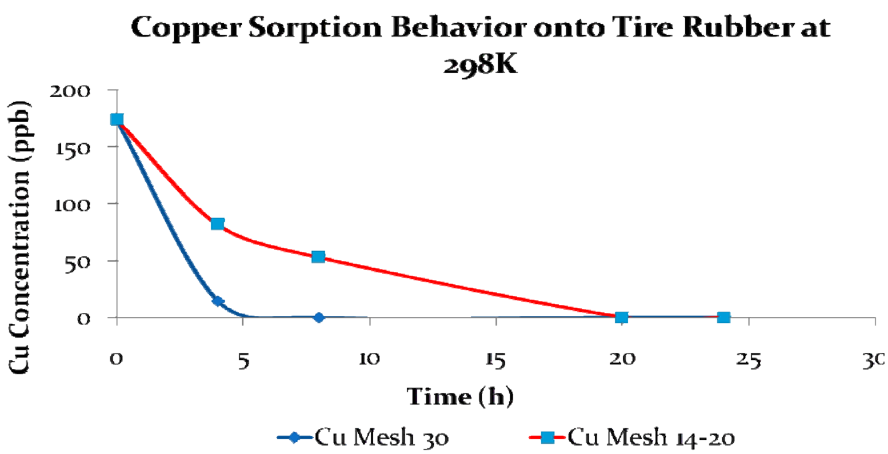


Figure 7. Sorption of Cu ions by WTCR at pH 6. The concentration of the sorbent was 10 g/L

As figure 7 shows, the concentration of copper is almost depleted after 4 hours using mesh 30. The complete Cu removal took place after 20 hours when the larger size (mesh 14-20) was used. Evidently, the smaller the size of the sorbent, the higher the availability of sorption sites in the WTCR (carbon black). In a different experiment, WTCR mesh 30 was contacrted with a solution containing 0 ppb of each Cu and Pb (MT 100) and 100ppb of each Cu and Pb (MT 200) at the same conditions as the previous experiment. The percent of Cu and Pb removal was between 96% and 98% irrespective of the total concentration of metal ions. As evidenced, the removal of Cu and Pb was very efficient when WTCR was used as sorbent. However, the main concern is the release of Zn ions (from ZnO component in tire rubber) from the sorbent. A Zn concentration as high as 1ppm was detected in the solutions at the end of the sorption stage.

3.4 Adsorption tests: Combined schemes

The previous sections have verified the sorption capability of both, the WTCR and the dewatered sludge. The main difference is in the sorption rate: the sorption of Cu and Pb was faster when WTCR was used than the sludge. However, the sludge was capable of removing Zn ions, whereas the WTCR was not. Therefore, it seemed reasonable to use the two sorbent in a two-stage process. First, the solution will be contacted with WTCR (10g/L, pH 6.0, 24 hours) for early removal of Cu and Pb. The solution, after recovery of the WTCR, will be then contacted with dewatered sludge (10 g/L, ph 8.0, 24 hours) for the removal of Zn species. In a different experiment 20g/L of rubber and sludge were used.

As the data in the following table suggests, the terminal concentration of Zn ions was below the environmental regulation in both experiments (10g/L and 20g/L sorbents). However, the terminal concentration of Pb and Cu were still above the limit values.

Table 4. Terminal concentrations, $C_{f,}$ and removal efficiency for heavy metals by using WTCR and Sludges at 10g/L and 20g/L of each sorbent. The initial concentration of metal ions was 90ppb.

Metal	10g/L C_f (ppb)	% Removal	20g/L C_f (ppb)	% Removal
Cu	26.4	81	18.6	81
Pb	8.9	96	5.4	95
Zn	27.5	88	41.0	55

Another attempt considered the use of WTCR followed by chemical precipitation with NATC. In this experiment 10g/L of WTCR was contacted with a 100ppb solution of each metal, Cu, Zn, and Pb for 24 hrs on a shaker bath at pH 6.0. The exiting solution was treated by 15ppm of NATC (this concentration represents 1.5 times the recommended NATC concentration) and 250ppm of GC-850 coagulant. The pH was 8.0 and the contact time in ach stage, 24 hours. The results are summarized in the following table.

Table 5. Terminal concentrations, $C_{f,}$ and removal efficiency for heavy metals by using WTCR (10g/L and 20g/L) and 15ppm of NATC. The initial concentration of metal ions was 100ppb.

Metal	10g/L C_f (ppb)	% Removal	20g/L C_f (ppb)	% Removal
Cu	18.4	87	6.3	94
Pb	5.2	95	2.9	98
Zn	23.1	88	47.3	44

In this case, the terminal concentrations of Cu, Pb and Zn were as low as required by the environmental regulations.

4. Training and Publications.

Thanks to additional support from the Departments of Engineering Sci. & Materials and Chemistry at URPM as well as donations from REMA Inc. and TOYOTA Foundations, we were able to involve two graduate students (one MS, one PhD), both from Chemistry Department, and three undergraduates (two from Chemistry and one from Chemical Engineering). Miss Diana Sanchez, received her MS degree after presenting her results on the use of waste tire crumb rubber to remove heavy metal ions from water. Now, she has been accepted as a PhD student and is still working in our group. Mr. Luis Alamo, worked on the evaluation of the crumb rubber to remove organic solvents (BTX) from water. He received his MS degree after presenting his corresponding results. He has also been enrolled as a PhD student and continues working in our group. Miss Aixa del Valle, undergraduate student from the department of Chemical Engineering was working in our laboratories for one year (May 2007-May 2008). She received the financial support from the PR-LSAMP Program.

Field of study	Undergraduate	MS degree	PhD degree	Post PhD	TOTAL
Chemistry	02	01	01		04
Chemical Engng.	01				01

Various presentations (posters and papers) have been produced as a consequence of the progress of our work. As an example, the following peer-reviewed papers have been published recently.

- L. Alamo, F. Roman and O. Perales-Perez. Sorption of ethylbenzene, toluene and xylene onto crumb rubber from aqueous solutions. Nanotech, vol. 4, 675, (2007).
- J. Lopez-Morales, S. Nieto-Zambrano, F. Roman-Velazquez, and O. Perales-Perez. Evaluation of the Adsorption Behavior of Tetracycline onto Crumb Rubber in Aqueous Solution. Proceedings 7th Caribbean Island Water Resources Congress, 87, (2007)
- L. Alamo-Nole, F. Roman, and O. Peralez-Perez. Use of Recycled Tires Crumb Rubber to Remove Ethylbenzene, Toluene and Xylene in Single Component, Multi-Components Systems and Gasoline from Aqueous Solutions. Proceedings 7th Caribbean Island Water Resources Congress, 92, (2007)
- D. Sanchez, L. Alamo, A. del Valle, F. Roman, and O. Perales-Perez. Removal of Lead, Copper, and Cadmium Ions from Aqueous Solutions using Waste Tire Crumb Rubber. Proceedings 7th Caribbean Island Water Resources Congress, 97, (2007)

Mayagüez, May 30, 2008

Information Transfer Program Introduction

None.

Seventh Caribbean Islands Water Resources Congress

Basic Information

Title:	Seventh Caribbean Islands Water Resources Congress
Project Number:	2007PR37B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	Management and Planning, Water Supply, Water Quality
Descriptors:	
Principal Investigators:	Jorge Rivera−Santos, Walter Silva

Publication

1. USVI WRRI and PRWRERI, Proceedings of the 7th. Caribbean Island Water Resources Congress, St. Croix, USVI,October 25−26, 2007. (in CD)

SEVENTH CARIBBEAN ISLANDS WATER RESOURCES CONGRESS

The Seventh Caribbean Islands Water Resources Congress (CIWRC) was held on October 25-26, 2007 at the University of the Virgin Islands in St. Croix, US Virgin Islands. The congress was sponsored and organized by Virgin Islands Water Resources Research Institute, Puerto Rico Water Resources and Environmental Research Institute, and U.S. Geological Survey. The Congress program was organized to facilitate presentation of papers on the wide range of topics that are relevant to the continually growing needs of the islands. The program aimed to provide (1) an exchange of ideas and information for water resources investigators, educators, consultants, and management professionals; (2) an update on the current water resources situation in the Tropics and the Caribbean; and (3) sharing and transfer of data, technology, and management practices.

Call for Abstracts Process

Four (4) to five (5)-page Extended Abstracts for individual oral and poster presentations were sought on the following or related topics, as shown in Appendix 1.:

- Watershed management
- Infrastructure and water distribution
- Erosion, sedimentation and geomorphology
- Data availability
- Extreme hydrologic events (floods/droughts, hurricanes)
- Sustainable development of water resources
- Desalination, water reuse, and other water-supply sources (Caribbean and Tropical Islands experience)
- Advances on water sanitation
- Climate change impact in the Tropics/Caribbean (global changes, El Niño, La Niña)
- Management of limited freshwater resources (conservation, reuse, availability)
- Water resources information and education
- Surface and ground water quality
- Social aspects and water issues: water price, water use, etc.
- Small community water supply and wastewater systems
- Undergraduate (or graduate) education
- Rainwater harvesting – quantity and quality issues

The first call for abstracts was made out on April 27, 2007. It was delivered via emails and physical mails to various professionals in different locations. The submission of an extended abstract was due on June 29, 2007. After a peer review process, acceptance was notified to the corresponding authors on August 31. The authors again were required to submit a camera-ready final paper by September 21, 2007.

Peer Review Process

All extended abstracts submitted were peer-reviewed. The review criteria were 1) originality, 2) status of project, 3) technical content, 4) benefit and significance, and 5) quality, as follows:

- Originality - The abstract should deal with new concepts or novel applications of established concepts. It may describe substantial improvements of existing theories or present new data in support and extension of these theories. Comparative or supportive data should be included.
- Status of Project - The abstract should establish that the project is well-developed and should present data or results to support the hypothesis. Data should have been subjected to preliminary analysis, at a minimum. Preferences will be given to abstracts showing concrete results with practical applications.
- Technical Content - Objectives and scope of the project should be stated. The conditions under which the data were obtained and the general procedures/methodology used should be presented. Conclusions should be drawn directly from the investigation.
- Benefits & Significance - Actual benefits and widespread applications should be reported. What contributions has the project made towards improving water resources? Does the method described save time and money? Is it more accurate? Is it more effective? Is this an unusual case or typical of general applications?
- Quality - The adequacy of an abstract is considered indicative of the quality of the final paper and of the presentation. Authors should prepare their abstracts with care, paying attention to style, organization of the abstract, and accuracy of data presented.

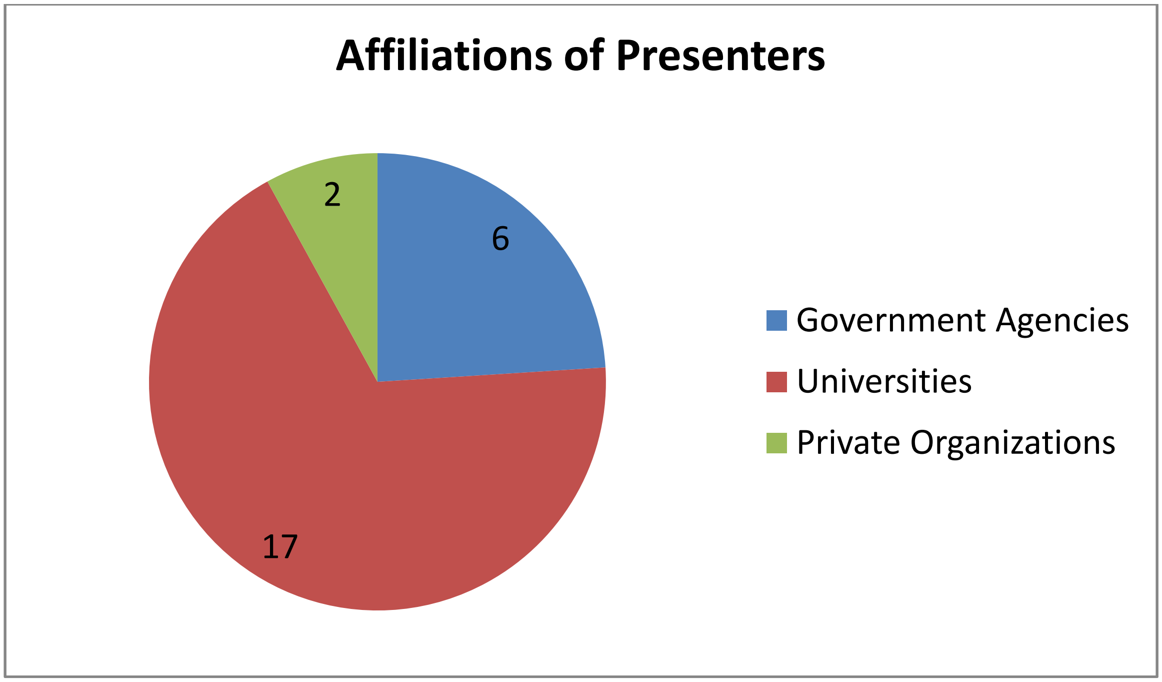
Acceptance notice with the peer-review results and a guideline for the final paper were delivered to the corresponding authors on Aug 31, 2007 and a final paper submission was requested by September 21, 2007.

Congress Statistics

A total of fourteen platform presentations and eight poster presentations were made during the Congress. In addition, the Congress had a plenary talk and two lunch-and-talks as well as two exhibitors. The Congress hosted a total of forty-five (45) participants. To achieve the most effective delivery of the presentations, four sessions with similar topics were held. A moderator was assigned to facilitate each session. The session titles were as follows:

- Watershed Management
- Advances in Water Sanitization
- Surface and Groundwater Quality
- Management of Limited Freshwater Resources

The Congress drew significant attention from many different origins of countries and organizations. The following graphs show statistics among 17 platform (3 invited talks and 14 presentations) and 8 poster presentations. The affiliation and place of origin of the presenters is shown in Figure 1. Student's participation was also active. One graduate student from Canada and two undergraduate students from Puerto Rico made their platform presentations.



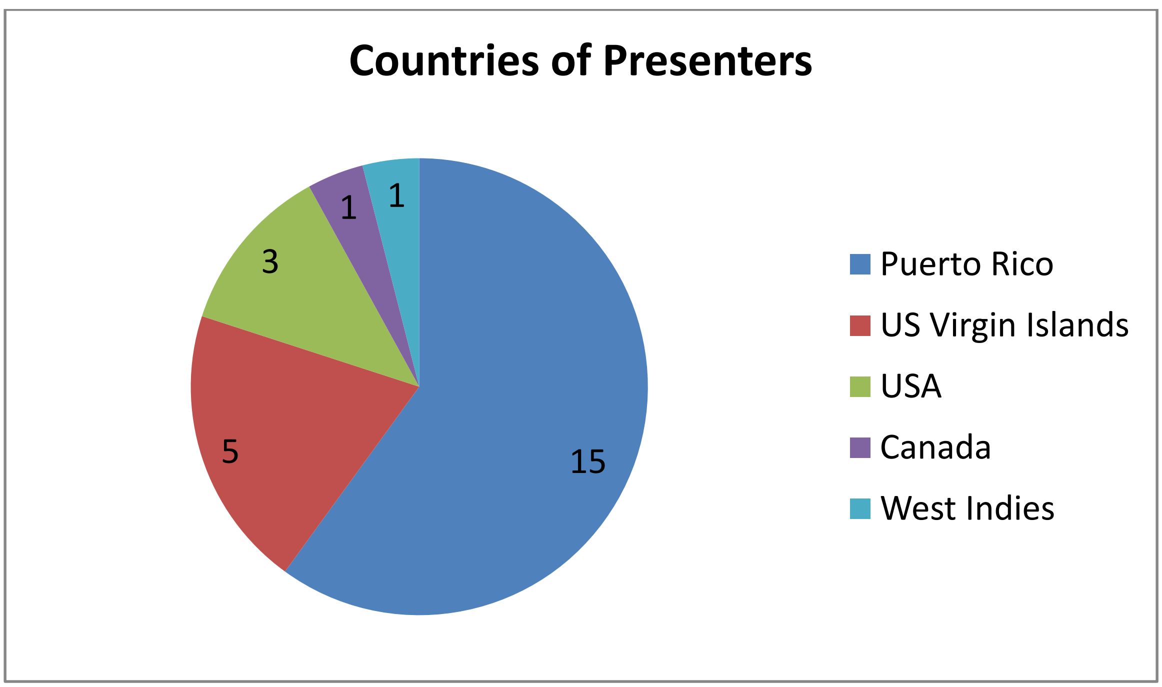


Figure 1. Affiliation and place of origin of the presenters at the 7th CIWRRC

Preparation of Proceedings

Proceedings of the 7th CIWRC were made with the peer-reviewed final papers accepted for oral and poster presentations. All participants to the Congress received the proceedings burnt in a CD at the registration desk during the Congress. The proceedings totaled 111 pages with a cover page as shown in Figure 2.

Official Program

Early in November 2008, an official program was made and sent to all presenters. This was done to help them build professional contacts for future collaborations. The 4-page official program included general and technical information on the Congress (Please refer to the Appendix 2).

SEVENTH CARIBBEAN ISLANDS
WATER RESOURCES CONGRESS

OCTOBER 25 – 26, 2007
UNIVERSITY OF THE VIRGIN ISLANDS
ST. CROIX, USVI

PROCEEDINGS

PROCEEDINGS

SEVENTH CARIBBEAN ISLANDS WATER
RESOURCES CONGRESS

Edited by

Sangchul (San) Hwang, Ph.D.
Department of Civil Engineering and Surveying
University of Puerto Rico at Mayaguez
Mayaguez, Puerto Rico 00681-9041

Sponsored by

VIRGIN ISLANDS WATER RESOURCES RESEARCH INSTITUTE

PUERTO RICO WATER RESOURCES AND ENVIRONMENTAL
RESEARCH INSTITUTE

UNITED STATES GEOLOGICAL SURVEY

OCTOBER 25 – 26, 2007
UNIVERSITY OF THE VIRGIN ISLANDS
ST. CROIX, USVI

Figure 2. Cover page of the Proceedings of the 7th CIWRC (Available in CD)

APPENDICES

APPENDIX 1. Call For Abstacts

SEVENTH CARIBBEAN ISLANDS WATER RESOURCES CONGRESS

CALL FOR ABSTRACTS & ANNOUNCEMENT

SEVENTH

CARIBBEAN

ISLANDS

WATER

RESOURCES

CONGRESS

SPONSORS

Virgin Islands

Water Resources Research Institute - UVI

Puerto Rico

Water Resources and Environmental Research Institute

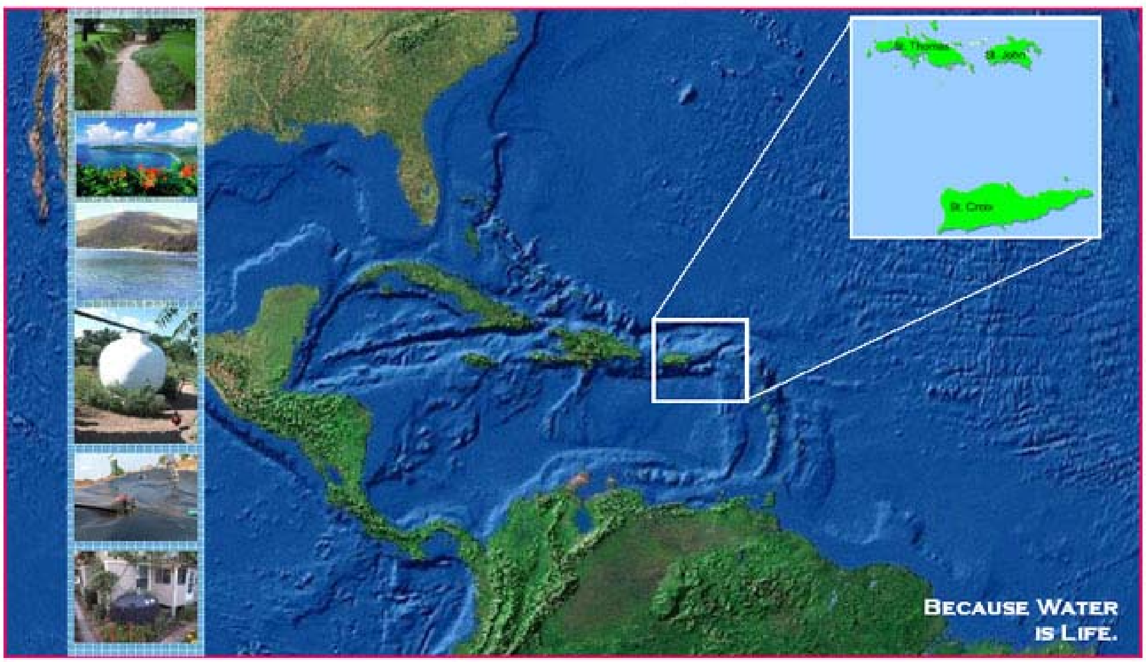
U.S. Geological Survey

October 25 – 26, 2007

Saint Croix, Virgin Islands

- Official Program -

SEVENTH CARIBBEAN ISLANDS WATER RESOURCES CONGRESS



E-Mail: prwreri@uprm.edu
Web: http://prwreri.uprm.edu/7CIWRC

October 25 – 26, 2007

University of the Virgin Islands

Saint Croix, US Virgin Islands

7th CIWRC

SEVENTH CARIBBEAN ISLANDS WATER RESOURCES CONGRESS

The Seventh Caribbean Islands Water Resources Congress (CIWRC) was held in October 25-26, 2007 at the University of the Virgin Islands in St. Croix, US Virgin Islands. The congress was sponsored and organized by Virgin Islands Water Resources Research Institute, Puerto Rico Water Resources and Environmental Research Institute, and U.S. Geological Survey.

The Congress program was organized to facilitate presentation of papers on the wide range of topics that are relevant to the continually growing needs of the islands.

The program aimed to provide (1) an exchange of ideas and information for water resources investigators, educators, consultants, and management professionals; (2) an update on the current water resources situation in the Tropics and the Caribbean; and (3) sharing and transfer of data, technology, and management practices.

Congress Statistics:

17 Platform Presentations

8 Poster Presentations

45 Attendees

2 Exhibitors

Contacts:

PR Water Resources and Environmental Research Institute

P.O. Box 9040

Mayagüez, PR 00681-9040

Phone: (787) 832-4040 x3781

Fax: (787) 833-3985

Email: PRWRERI@uprm.edu

Congress General Chair

HENRY H. SMITH

Virgin Islands Water Resources Research Institute

(340) 693-1062

Fax: (340) 693-1065

E-Mail : hsmith@uvi.edu

Congress Technical Program Chair

SANGCHUL HWANG

Dept. of Civil Engineering

Univ. of Puerto Rico at Mayaguez

(787) 832-4040 x3454

Fax: (787) 832-8260

E-Mail: shwang@uprm.edu

Congress Co-Chairs

JORGE RIVERA-SANTOS

PR Water Resources and Environmental Research Institute

(787) 832-4040 x.3781

Fax: (787) 833-3985

E-Mail: PRWRERI@uprm.edu

PEDRO L. DIAZ

US Geological Survey

(787) 749-4346 x222

Fax: (787) 749-4301

Email: pldiaz@usgs.gov

PLENARY TALK,

LUNCHEON-TALKS

&

TECHNICAL PRESENTATIONS

CARAMBOLA BEACH RESORT

Estate Davis Bay

Kingshill, St. Croix

US Virgin Islands 00851
Phone 340-778-3800

SEVENTH CARIBBEAN ISLANDS WATER RESOURCES CONGRESS

Plenary Talk

Mr. Matthew Larsen

US Geological Survey

Topics: USGS Initiatives in the Caribbean Region

8:20 am – 9:00 am, October 25, 2007

NWW Great Hall

Luncheon-Talks

Mr. Luis Raul Jimenez

CDM

Topics: "Program Management for the PRASA Capital Improvements"

Lunch time, October 25, 2007

NWW Great Hall

Mr. Aaron Hutchins

VI Department of Planning and Natural Resources

Topics: "Water Quality Initiatives in the U.S. Virgin Islands"

Lunch time, October 26, 2007

NWW Great Hall

Contacts:

PR Water Resources and Environmental Research Institute

P.O. Box 9040

Mayagüez, PR 00681-9040

Phone: (787) 832-4040 x3781

Fax: (787) 833-3985

Email: PRWRERI@uprm.edu

Technical Presentations

Subjects of:

- Watershed Management
- Advances in Water Sanitization
- Surface and Groundwater Quality
- Management of Limited Freshwater Resources

14 Platform Presentations – NWW Great Hall

8 Poster Presentations – REC Room # 133

Exhibitions

Air Water World, Inc., CO

RPD Contractors MEI, Corp., PR

Welcoming Reception

Carambola Hotel

5:00 pm – 8:30 pm, October 25, 2007

Official Program of Technical Presentations

Time		25-Oct-07		26-Oct-07	
Time		Watershed Management (Moderator: Walter Silva_UPRM)	Advances in Water Sanitization (Moderator: San Hwang_UPRM)	Surface and Ground Water Quality (Moderator: Pedro Diaz_USGS_PR)	Management of Limited Freshwater Resources (Moderator: Adrian Cashman_U. West Indies)
8:00	8:20	*Welcoming (Henry H. Smith, Congress General Chair), Opening Remarks (Dr. LaVerne E. Ragster, UVI President), and On-site Registration*			
8:20	9:00	**Plenary Talk: Matthew Larsen (USGS), "Caribbean Islands, Global Change, & Water Resources"**		*Welcoming (Jorge Rivera-Santos, Congress Co-Chair), and On-site Registration*	
9:00	9:30	"Caribbean Water Management Implications of Potential Climate Change" by Adrian Cashman et al. (U. West Indies)		"Groundwater Levels in Puerto Rico, 1987-2006" by Ron Richards (USGS_PR)	
9:30	10:00	"Numerical Simulation of Rivers in Floodplains" by Walter Silva and Alejandra Rojas (UPRM)		"Effects of Aquifer Development and Changes in Irrigation Practices on the Groundwater Discharge to the Jobos Bay National Estuarine Research Reserve, South-Central, Puerto Rico" by Jesus Rodriguez and Jose Rodriguez (USGS_PR)	
20-min Coffee Break		Poster Presentations and Exhibitions (REC Room # 133)			
10:20	10:50	"The Role of a Community-based Nongovernmental Organization in promoting Active Research and Stewardship of Water and Other Environmental Resources in the US Virgin Islands" by Sharon Coldren (CBCC, VI)		"Effectiveness of Mandatory Law of Cistern Construction for Rainwater Harvesting on Supply and Demand of Public Water in U.S. Virgin Islands" by Hossana Solomon and Henry Smith (UVI)	
10:50	11:20	"Effect of Spatial and Temporal Resolution Uncertainty on Predicted Best Management Practice (BMP) Efficiency" by Rob Miskewitz et al. (Rutgers U., USA)		"Use of Stable Isotopes to Determine Potential Sources of Nitrate and Contribution of Surface Water to Aquifer Recharge in the Salinas Area, South Coastal Plain Alluvial Aquifer, Puerto Rico" by Jose Rodriguez (USGS_PR)	
Lunch		Luncheon Talk: Luis Raul Jimenez (CDM), "Program Management for the PRASA Capital Improvements"		Luncheon Talk: Aaron Hutchins (VI Department of Planning and Natural Resources), "Water Quality Initiatives in the US Virgin Islands"	
1:00	1:30	"Sediment Production from Natural and Disturbed Surfaces in Dry Tropical Areas of La Parguera, PR, 2003 - 2005" by Carlos Ramos (U. Texas_USA)			"Water Resource Development" by May Adams Cornwall (VI Waste Management Authority)
1:30	2:00	"The Caribbean Water Initiative (CARIWIN)" by Alicia Suchorski et al. (McGill U., Canada)			"Intensive Tank Culture of Tilapia in the UVI Biofloc System" by James Rakocy et al. (UVI)
20-min Coffee Break		Poster Presentations and Exhibitions (REC Room # 133)			
2:20	2:50		"Hydraulic and Biochemcial Characteristics of Coal Combustion Byproducts Aggregates as Alternative Daily Cover for Landfills" by Arelys Fonseca et al. (UPRM)		"Romoval of Cadmium, Copper & Lead from Aqueous Solutions Using Waste Tire Crumb Rubber as Sorbent" by Felix Roman et al. (UPRM)
2:50	3:20		"Telemetry Monitoring of Small Water Supply" by Sacha Sanchez et al. (UPRM)		
3:20	3:50		"Innovative on site Wastewater Disposal Systems Outreach and Demonstration Project" by Rafael Davila et al. (UPR)	Closing Remarks (Pedro L. Diaz, Congress Co-Chair)	
3:50	5:00	Poster Presentations and Exhibitions (REC Room # 133)			

Poster Presentations

1	"Evaluation of the adsorption behavior of tetracycline onto crumb rubber in aqueous solution" by Jose Lopez et al. (UPRM)
2	"Use of recycled tires crumb rubber to remove ethylbenzene, toluene and xylene in single componebt, multi-components systems and gasoline from aqueous solutions" by Luis Alamo et al. (UPRM)
3	"Removal of lead, copper, and cadmium ions from aqueous solutions using waste tire crumb rubber" by Diana Sanchez et al. (UPRM)

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR−USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	4	0	0	0	4
Ph.D.	1	0	0	0	1
Post−Doc.	0	0	0	0	0
Total	6	0	0	0	6

Notable Awards and Achievements

Publications from Prior Years