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Front Cover: Rice Bay Formation, looking southwest along Grotto Beach. Photograph by Sandy Voegeli.

Back Cover: Dr. John Milliman, The College of William and Mary. Keynote Speaker for the 13th Symposium. Photograph by Sandy Voegeli.

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INTEGRATING FIELD EXPERIENCES IN ENVIRONMENTAL SCIENCE AND COMMUNITY SERVICE: LESSONS LEARNED FROM SAN SALVADOR, BAHAMAS

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ABSTRACT

Environmental science courses are an attractive option for infusing science across disciplines and within the context of a cross-cultural experience. San Salvador Island, Bahamas, is an ideal site to engage students in all aspects of environmental science. It is a small, remote outer island with a population of roughly 900--located away from the large population centers and heavy tourist areas of New Providence and Grand Bahama Islands. However, San Salvador is not immune from development, and one of the goals of this course is to focus on teaching concepts of sustainable resource utilization to students from the United States as well as from San Salvador. There are several case studies based on recent construction projects on the island where students can apply basic geological principles, while assessing short term and long term gains and losses these facilities provide the community.

In this contribution, we provide examples from our respective environmental science courses illustrating the use of case studies, including pertinent background information and student exercises and assessment. Because service learning is becoming an integral part of undergraduate curricula, we provide examples of service learning activities that we have integrated into our courses. Finally, we provide an example of course outcomes and assessment criteria used for environmental science courses.

INTRODUCTION

The Course

Environmental Science encompasses a number of fields within the natural and social sciences (Figure 1). A course in environmental science taught on San Salvador Island (Figure 2) is by nature a field-oriented course that emphasizes human impacts on the fragile tropical reef and carbonate island ecosystems. This course is a combination of evening lectures and site visits during the mornings and afternoons. The course is often "front loaded"; that is, it demands writing assignments based on papers and reports from students before departing to the island.

In this paper, we present some of the exercises we have used in our courses, along with applicable background content regarding several environmental issues used in class. It is our objective to not present a detailed, scholarship of the teaching and learning approach, but rather to provide a set of activities and issues that faculty from other institutions could extract and use in their own classes.

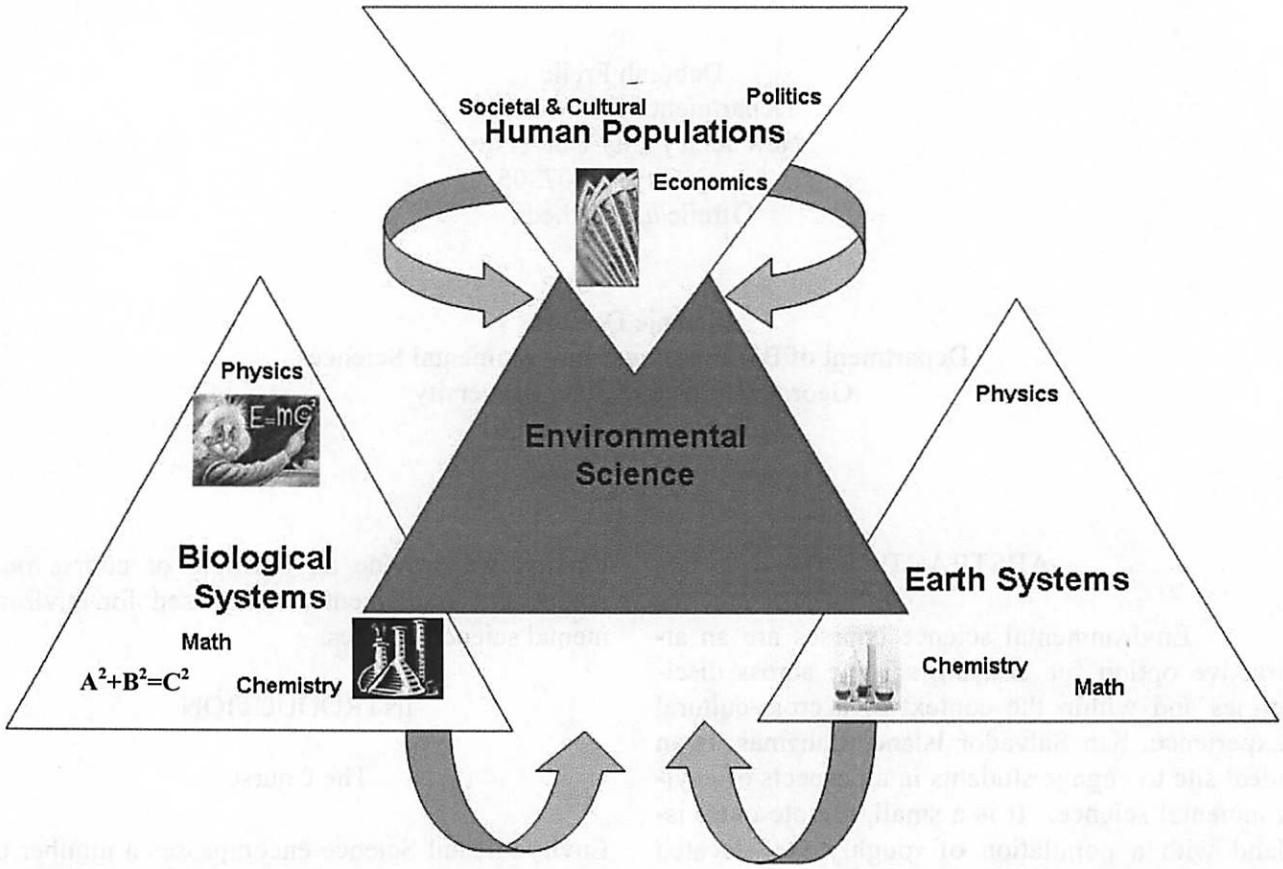

Figure 1. Interrelationships of fields that constitute Environmental Science.

Location and Environmental Issues

The course is held at the Gerace Research Centre (GRC), a former U.S. Navy submarine tracking station on San Salvador Island (Figure 3), Bahamas. The GRC is a well-known marine field station that provides housing and prepared meals for students, excellent laboratory and teaching facilities, and field vehicles. There are a number of sites (Figure 3) that are ideal for illustrating a wide range of environmental issues.

The Bahamas Environment, Science & Technology Commission (BEST) manages the implementation of multilateral environmental agreements and reviews environmental impact assessments and environmental management plans for development projects within The Bahamas. BEST conducted a survey on 13 Family Islands to determine environmental issues as part of the National Capacity Needs Self Assessment Project (2004). The following issues where identified on San Salvador:

1) Lack of emergency infrastructure for fires
2) Poaching
3) Sand mining
4) Lack of safe disposal methods for medical wastes, motor oils and other hazardous household wastes
5) Stability and impact of the new seawall

6) Destruction and/or deterioration of historical sites
7) Lack of disposal options for sewage sludge
8) The unfinished marina and its destruction of the groundwater lens

Surprisingly, freshwater availability was not listed as a major environmental issue for San Salvador in this study.

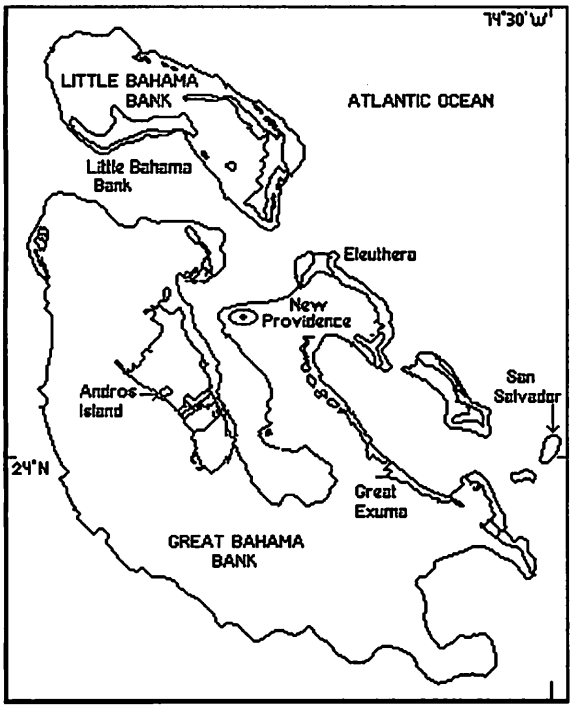

Figure 2. Map of the Bahamas showing location of San Salvador, a 15km by 8km eastern most island of the Bahamian archipelago. (From: http://www.unesco.org/csi/pub/papers/gerace.htm)

COURSE STRUCTURE

The environmental science courses offered by both authors utilize many different resources and methodologies to make it an enriching and integrative experience:

1) The island and its residents--the students benefit the most from experiencing the sites and people of the island
2) Lectures covering principles needed to understand environmental issues pertaining to the island
3) Documents and reports available on government and non-governmental organization websites
4) Guest lecturers (i.e. fellow colleagues at the station);
5) Field notebooks
6) Debriefing sessions
7) Outreach and service learning activities

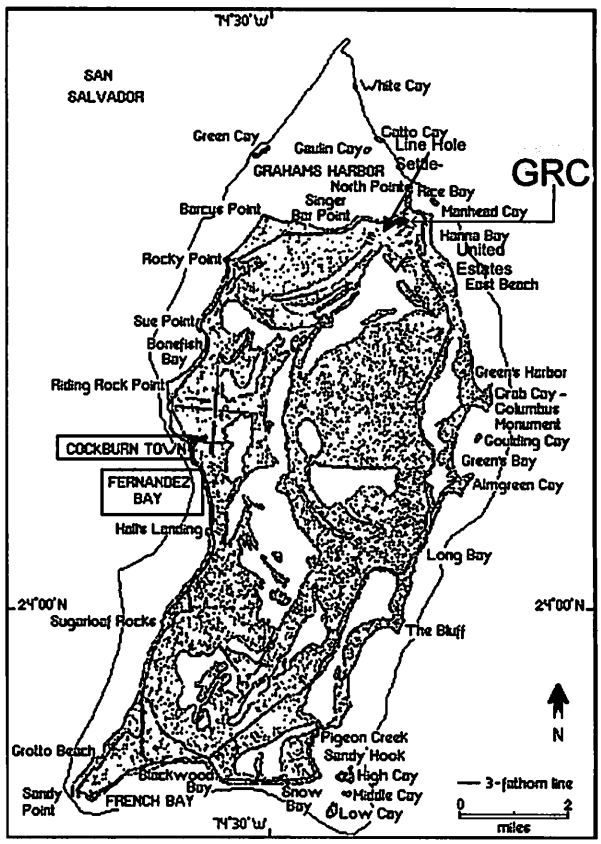

Figure 3. Map of San Salvador showing areas of interest-including Gerace Research Centre, United Estates, Landfill, East Beach, Line Hole Settlement, Riding Rocks, Cockburn Town and Fernandez Bay (modified from http://www.unesco.org/csi/pub/papers/gerace.htm)

Students are provided with readings and lectures on various topics, including coastal processes, groundwater resources and karst geology and geomorphology. Evaluation is based

on responses to questions using sound geological principles and integration of the human dimension of environmental issues covered in the course. Open-ended essay questions are used as a tool to determine student competence in the following skill areas: 1) presentation of accurate scientific content; 2) application of scientific principles to environmental issues; 3) ability to generate multiple "solutions" to an issue; 4) evaluation of potential solutions and selection of one to employ; 5) ability to estimate human responses and factors that could deter employing the "best" practice, and 6) ability to communicate orally and in writing.

Case Study 1: Background on Coastal Erosion Issues

Students learn the basic concepts of coastal processes and the impacts of hurricanes and storm surges on shorelines. They are also taught three approaches to controlling coastal erosion: 1) hard stabilization (i.e. seawalls, groins, jetties); 2) soft stabilization (i.e. beach re-nourishment) and 3) relocation, the approach favored by many coastal geologists (e.g. Orrin Pilkey *Living with the Shore Series*), but not always a feasible one for an island community where area for road placement is extremely limited.

Economics. The Queen's Highway is the major and only road accessible to the entire island and is vital for commerce and transportation on San Salvador. As such, it needs to be protected from the effects of coastal erosion. To do so, a seawall capable of withstanding hurricane-force winds and storm surges needs to be built and maintained on parts of the island to ensure that slumping and undercutting does not damage the roadway and disrupt transportation. The 'new' seawall, which is really more of a bulkhead (a relatively low wall designed to hold land) was built in 2004 after Hurricane Floyd hit the island in 1999. This construction effort was the result of a $21 million loan to the Bahamas in March, 2001 by the Inter-American Development Bank for the reconstruction and rehabilitation of infrastructure in the Family Islands (anonymous, 2001). Additionally, the then-Minister of Agriculture, His Excellency Alfred Gray (2001), mentioned in a speech given to the Food and Agriculture Organization of the United Nations in 2001, "Damages to boats, bridges, docks, seawalls, warehouses and electrical supplies limited our ability to import, store and transport food effectively. Moreover, funds which were earmarked for national development in other areas had to be diverted to rebuilding, repairing and reconditioning infrastructure, including seawalls, roads, storage buildings, and restoring electricity and other communication systems".

Seawalls; Help or Hindrance. A report (USACOE, 2004) based on a study by the Organization of American States entitled *The Bahamas National Report Integrating Management of Watersheds and Coastal Areas in Small Island Developing States (SIDS) of the Caribbean,* stated that "in some cases, waves overtopping the sea defenses caused shoulder and road washouts on the landside of the seawall. The conditions worsened as the seawalls acted as a barrier to the wave surges returning to the ocean. Waves and surges also caused erosion and destruction of the natural vegetation cover." In other words, the seawalls were more of a hindrance than a help to the islands.

Student Involvement and Reflection. Given this information, students are asked to carefully observe and compare the seawall in Cockburn Town with the wall located south along Fernandez Bay. Classes stop at several points along the seawall and are asked to describe its condition at Cockburn Town (Site 1) (Figure 4), Bamboo Point (Site 2) (Figure 5) and Fernandez Bay (3-5) (Figure 6). After careful observations and reflection, students assess the effectiveness of the seawall. In their field notebooks, they respond to the following questions related to where they see slumping, potential for road washouts and the destruction of dune vegetation.

Students also compare seawall and coastal protections measures between San Salvador Island and their own state (Georgia or New Jersey). The students are told to compare the use of seawalls in the United States to San Salvador, specifically addressing the following questions.

- Are there cases where seawalls are effective? If yes, describe the circumstances?
- Can you think of any examples of carbonate dominated beaches (think Florida Keys) where seawalls have been used?
- Why can't carbonate coastal environments be managed the same way as clastic, terrigenous beaches?

Figure 4. Seawall at Cockburn Town looking northward toward the radio towers and Catholic Church. Beachrock is in foreground.

Figure 5. Broken seawall near Rocky Point.

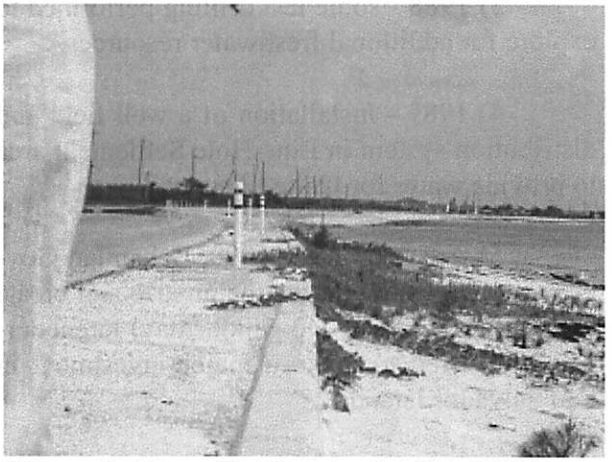

Figure 6. Seawall at Fernandez Bay looking south. Queens' Highway is on left. White poles demarcate the wall edge.

Case Study Two: Water Use History for San Salvador Island

In this exercise, students are provided with a timeline describing the water resource use on San Salvador Island since the 1950's. This information is based on an April 28, 2006 – address by Bradley B. Roberts M.P., Minister of Works and Utilities, who outlined freshwater availability on the island during the contract signing ceremony for the water main extension into United Estates. The title of his presentation was *Water Relief for San Salvador* (2006a). The information about water usage on the island is summarized below:

1) 1955, 1967, 1971, 1972, and 1974 - groundwater surveys found freshwater sources scarce or lacking. Freshwater sources for the island were recognized at Cockburn Town airfield; the region near the development of Columbus Landing; and smaller bodies near Hard Bargain and Line Hole Settlement.

2) Late 1970's - A line of wells was installed on the north side of Cockburn Town airfield; the wells and the old catchment basin near the airport were used as water sources for Cockburn Town and nearby areas.

3) 1988 - some test drilling performed to explore for additional freshwater resources.

4) 1989 - installation of a well field and distribution system in Line Hole Settlement area to provide water for United Estates.

5) Approximately 1990, Bahamian Government agrees to enlarge the airstrip and create a water supply (>90,000 gallons/day) to encourage Club Med to make a major investment in San Salvador Island.

6) 1992 - After the airfield is constructed, groundwater resources are capable of producing a maximum of 80,000 gallons/day. Club Med, Cockburn Town and North Victoria Hill's water needs cannot be supported in a sustainable way, resulting in gross over pumping.

7) 1990's - The freshwater lens continues to be compromised and the salinity of both Cockburn Town's and United Estates' water rapidly increases becoming non-potable.

8) 2005 - Aqua Design Bahamas Limited (now GE) signs an agreement with the Corporation to provide water produced by reverse osmosis in a plant located in Cockburn Town well field. The plant is currently producing approximately 120,000 gallons/day.

9) 2006 - An agreement with Mr. Ian Greene (San Salvador Island) and his company Big N' Better to install some 12000 ft of 6 inch PVC pipe to connect the reverse osmosis water in North Victoria Hill to the system that serves United Estates is signed in April. The PVC pipes are slated to arrive on San Salvador before the end of May. Projected completion deadline is mid-August. The Bahamian Government estimates the cost of the project to be approximately $350,000, including trenching, materials, site supervision, and modifications to the system now in place in United Estates. Future plans include extending this system to provide water to Sugar Loaf and Long Bay.

With this information about the modern water availability and usage, students are also taken on field trips to observe 19th century plantation wells (Figures 7 and 8) and the field station's catchment area (Figure 9) and water treatment plant and water tanks (Figure 10) as well as the groundwater wells along line hole settlement, airport and across from the marina (Figure 12).

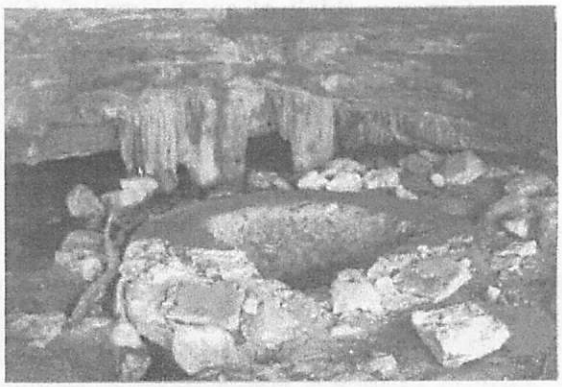

Figure 7. Plantation well at the southern end of the island, at the far edge of the estate associated with Watlings' Castle.

Figure 8. Plantation well, Line Hole Settlement well road.

Figure 9. Catchment at Gerace Research Centre looking southeast. Conduit is located towards the northern end of the basin (left in photo).

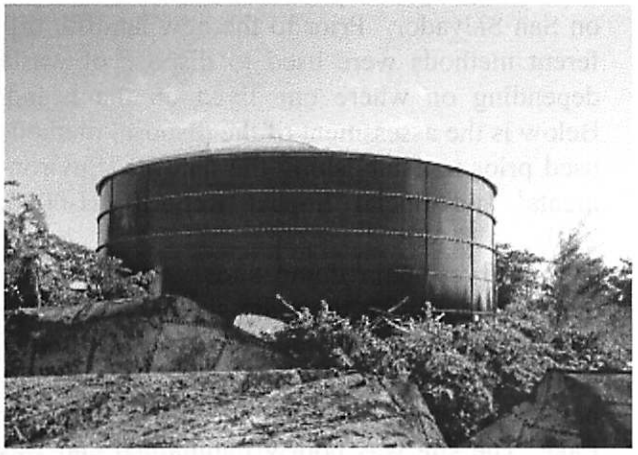

Figure 10. New water tank at Gerace Research Centre, constructed in 2006-2007.

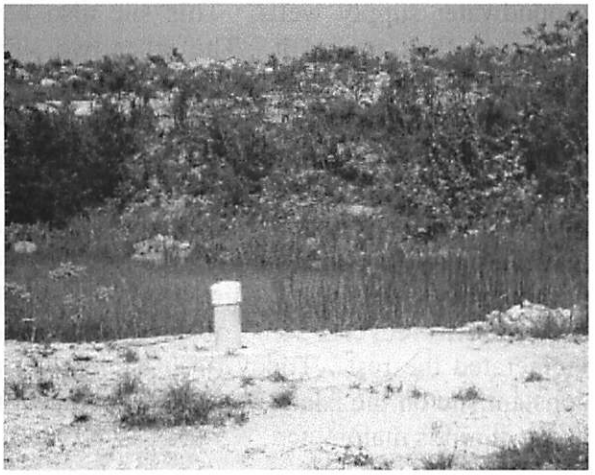

Figure 11. Groundwater well across the street from new marina.

Questions Pertaining To Water Resources

Given the information on the water usage and history of the island and field trips to historical areas around the island, students then are asked to assess the various scenarios proposed in 2004 by the US Army Corps of Engineers, for meeting water needs in the Bahamas:

- Groundwater provided via water authority on a large scale
- Private water wells
- Freshwater blended with brackish groundwater
- Groundwater barged in from one island to another
- Groundwater piped from one island to another by underwater lines
- Desalination (i.e. reverse osmosis) plants
- Transporting water from one part of the island to another
- Bottled water for drinking and cooking

Students respond to the following questions and directions in their field notebooks:

- How many of these means of meeting San Salvador Islands water needs have you observed on the island?
- Explain and describe the circumstances.
- Is there another option in use on the island that provides a significant source of freshwater?
- On a map of San Salvador, draw in the major areas of freshwater marshes and water-filled sinkholes.
- Indicate the major development sites of the last 25 years.
- What impact has development had on freshwater resources on the island?
- What has been the history of wetland use on San Salvador?
- Describe the value of wetlands and why they are so important for maintaining aquifers.

Case Study Three: Solid Waste Disposal-- Using a Historical Perspective Field Trips and Outreach

Historical Perspective.

Lucayan Occupation

While quite a bit is known about the Lucayan agricultural and fishing resource use, little is known about Lucayan solid waste disposal. Conch piles accreted in beach rock at Barker's Point and refuse piles elsewhere provide one of the few records of Lucayan life.

Loyalist Plantation

The Loyalist Farquharson plantation site can easily be seen from the road traveling along Queen's Highway adjacent to Pigeon Creek. Although the site is not accessible to a student group, students can get a sense waste disposal on the plantation. In general, waste was washed over the hill and there was no latrine (K. Gerace, personal communication). Sometimes visible piles of stones, removed during working the land after fences were completed, served as dump sites. Excavation of these dump sites have provided some invaluable clues to plantation life.

Fortune Hill is a plantation site that is suitable for a class visit. One of the octagon buildings covers a sinkhole that was used as a dump. The building itself may have been constructed to prevent animals from falling into the sinkhole (Kathy Gerace, personal communication).

The Loyalists modified sinkholes for water resources and an excellent well can be viewed on the west side of the dirt road to the Line Hole Settlement well field (Figure 8). Other sinkholes in the vicinity were modified to provide water sources for horses and other livestock.

Cold War Era

Burning solid waste has long been a common practice and is still observed today in some of the outer islands. However, evidence exists that the various military bases on the island used sinkholes as dump sites. A series of sinkholes just north of the dirt road leading to the Line Hole Settlement well field contains the remains of vehicles and occasionally drum remnants.

The Modern Tourism Boom

The San Salvador Island Landfill (Figure 13) was built in 2000-01 with support from the Bahamian Government and the Inter-American Development Bank. The new landfill is used extensively by all members of the community on San Salvador. Prior to the new landfill, different methods were used to dispose of waste depending on where one lived on the island. Below is the assessment of the disposal methods used prior to establishing the landfill (Environmental and Social Impact Report BH-0008: 2.10):

Three main dump sites were found on San Salvador, with the main site serving Cockburn Town, Club Med and Victoria Hill Settlement located about one-half mile from the airport in a depression along the shore of Little Lake. The site was poorly maintained and was seen by arriving passengers at the airport. Not only did it have solids and leachates overflowing into Little Lake, but it also flowed into the groundwater supply wells. This site also had numerous flies around it. The other two sites also had fly problems, as well as debris blowing across the landscape. These sites were located along roadsides and could be easily seen by visitors to the island. Solid waste collection was provided to island residents by contractors and was reasonably reliable, although indiscriminate dumping was and is still fairly common. Club Med used to recycles some of their wastes and incinerated the rest. Today trash haulers are a constant site on the island and waste segregation at the dump is maintained.

Figure 12. Active landfill north of Dixon Hill.

Figure 13. Leachate Pond at modern landfill.

<u>Students are taken to visit these various waste disposal sites and asked to answer questions and make directed observations.</u>

- Draw and label a diagram showing the layout of the San Salvador Landfill.
- Draw an overview and a cross-section that clearly shows the relationship between the cells and the leachate pond.
- What is used as a lining in the leachate pond?
- After a rain, the leachate pond fills and is usually empty within a couple of days. Do you think all of the water evaporates or can you describe another means of why the water disappears so quickly?
- Is there a thick evaporative crust on the lining of the landfill?
- What impact does the leachate pond have on individual wells, like the one Bernie Storrs has, located near the landfill?
- Examine the contents of the active cell. According to the Barbados Report (2004), Bahamians and visitors generate 264,000 tons of solid waste annually; Estimate what percentage of the items dumped in the landfills on San Salvador represents waste that was generated by residents vs. visitors?
- Why do you think cars and other large, steel items are simply discarded and not shipped off the island to be sold as scrap?

In addition to these questions and observations, the students also complete a beach clean-up. The activity is based on a lesson plan for Trash on Texas Beaches: An Investigative Field Trip/Lab Activity (2006b). Items are sorted based on whether they are plastic (including nylon rope), glass, aluminum, metal, or paper and cardboard. All items are weighed and subsequently taken to the landfill.

Figure 14. Debris found along East Beach (A.K.A. Junk Beach).

Figure 15. Collected materials along East Beach (i.e. Junk Beach) being weighed.

Table 1. Weight of items from the designated waste categories collected at Junk Beach. Total weight of all items collected was 257 pounds. Wastes were collected by 19 individuals (students and faculty) in 2.5 hours. Decay time based upon Pennsylvania Department of Natural Resources Beach Debris exercise (Anonymous, 2000).

Materials	Weight(Lbs)	Decay Time (yrs)
Plastics*	226	450
Glass	18	1000000
Metals(non Al)	3	80
Aluminum	2	150
Paper & Cardboard	2	0.8
* including nylon rope (18 Lbs)		

SCHOOL OUTREACH AND COMMUNITY ACTIVITIES

Community involvement began in 2004 when undergraduate students from our courses helped to paint the high school and dispose of trash. In 2005, each university student teamed up with two high school students and completed a beach clean-up. Large items were taken to the landfill and several bags of smaller items were taken to the school to be sorted based on the amount of time it took for the material to degrade. Both 10th graders and college students calculated the percentage of each class of waste and displayed the results in the form of a bar graph. Students also determined the source of discarded items.

In addition to the beach clean up activities, students from NJCU visited the San Salvador primary school. They went into the different classrooms and either helped the teachers with their daily lesson plans or they gave special presentations to the classes. Because many students in the NJCU program are obtaining their undergraduate degrees in Geoscience and either elementary/middle school or high school education, interacting with the primary school was important both culturally and as part of their teacher training (Figure 17). The Primary School was also given recycle containers for aluminum cans (provided by Georgia College & State University) (Figure 18). The class that collected the most cans received a prize at the end of the school year. A plaque was awarded

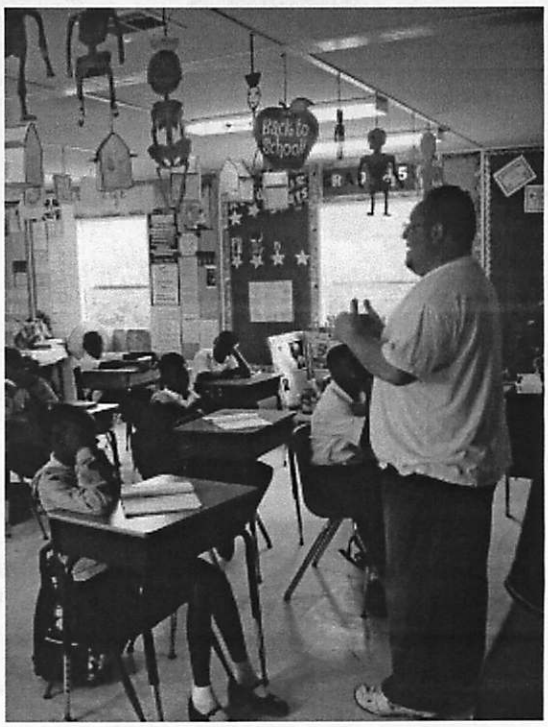

Figure 16. NJCU student, Justin Raia, teaching astronomy to students in the 5th Grade class at the local school.

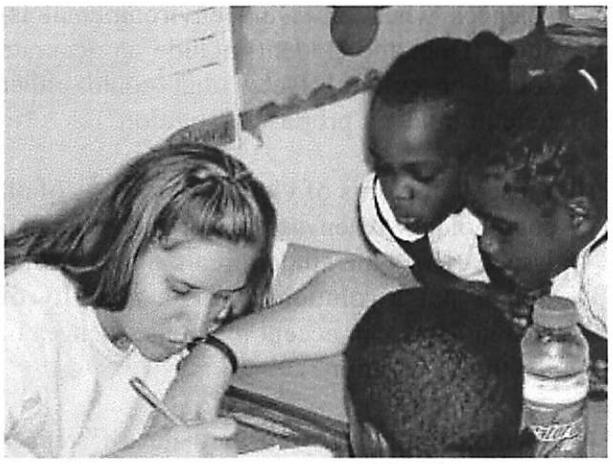

Figure 17. NJCU Student, Michelle Chmura helping 2nd Grade students.

Figure 18. Students with the recycle program at the Primary School.

to the 5th grade class in May, 2007 for collecting the most cans. This outreach and service learning could be easily replicated by other groups visiting the GRC, ensuring that the aluminum can recycling program continues on the island.

CONCLUSIONS

Student Assessment

One of the challenges of any course and particularly an intensive week-long field course in the Bahamas is how to assess student performance. In order to do this, we developed the following rubric (Table 2) and outcomes. These outcomes can be assessed using a rubric or other tool to evaluate student presentations, reflective statements as presented in field notebooks, and also the written exercises based on the questions given to them in this program.

Learning Outcomes

Each student is graded numerically (1-3) by having the following outcomes (1-11) placed in a rubric (Table 2).

1. Gather, analyze and synthesize data independently and in groups.

2. Use appropriate graphic displays of data (tables, graphs). (Are the graphs and tables properly labeled with captions; ease that the reader can grasp the concept based on the way data is visually presented).

3. Demonstrate proficiency in oral and written communication. (Are complete sentences, properly constructed and ordered paragraphs used).

4. Demonstrate cultural understanding and appreciation and how it relates to addressing environmental issues (e.g. student may recognize the role religion plays in the lives of Bahamians and addresses issues within the context of caring for the environment is also caring for God's world).

5. Utilize principles from multiple fields of science when addressing environmental issues. (Can the student understand why a certain organic molecule has a long residence time in the environment and how that relates to the way that compound travels in the groundwater and is absorbed by organisms).

6. Employ multiple working hypotheses when assessing environmental processes (student understands that there is not a single cause for the effect they see).

7. Uses accurate scientific content when assessing environmental issues; (is the scientific content both accurate and appropriate to describe the environmental issue).

8. Critique proposed solutions to environmental problems and project possible outcomes to those actions (student can offer a single solution, however, students who perform the best offer multiple "solutions" along with possible benefits and disadvantages of those solutions)

9. Develop and use knowledge of Bahamian economics, political science and other social sciences when assessing environmental issues. (Does the student include an accurate social or cultural factor that could either help or hinder a proposed "solution").

10. Present all points of view and interests of all shareholders when assessing environmental issues. (Does the student realize that a solution is not a solution unless a majority of shareholders can accept the consequences of its implementation?).

11. Demonstrate ability to mediate differences in opinions (does the student try to find a commonality among shareholders?).

Table 2. Rubric used for grading student outcomes. Learning outcomes 1-11 correlate with those explained in text. Assessment is graded numerically 1-3 or U if unable to determine for each student for each learning outcome.

Sample Assessment Data											
	Learning Outcome #										
Student	1	2	3	4	5	6	7	8	9	10	11
	3	3	3	3	3	3	3	3	3	3	3
	1	1	1	1	1	1	U	1	2	U	U
	2	3	1	2	U	1	U	2	2	2	1
	2	1	1	3	1	1	2	1	2	2	2
	1	3	3	1	1	1	U	1	2	2	3
	1	1	3	3	1	3	3	1	3	U	U
	2	2	2	2	2	2	2	2	2	2	1
Average	1.71	2.00	2.00	2.14	1.50	1.71	2.50	1.57	2.29	2.20	2.00
#U = uncertainity	0	0	0	0	1	0	3	0	0	2	2

Assessment Scale
3- High Level of Attainment
2-Moderate level of Attainment
1- Low Level of Attainment
U- Unable to determine

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