Report for 2001VI4201B: Teaching an Intensive Short Course on Water Resources, Coastal Hazards, and Coral Reef Degradation

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Report Follows:

Summary Report on

AN INTENSIVE SHORT COURSE ON WATER RESOURCES, COASTAL HAZARDS AND CORAL REEF DEGRADATION

Overview

In the Caribbean, issues of water supply, coastal erosion, and coral reef degradation are at the top of the environmental agenda. The islands in the region are relatively small and land use practices have an immediate and profound effect on the coastal environment that is important as a food supply, recreational area for residents and as the principal attractant for visitors in the tourism-based economy. It is critical then for all residents of the islands to have an understanding of the inter-relationship of all natural systems in the islands and to appreciate how each person has an important role in protecting these system.

This course was offered over a one-week period, July 16 to July 20, 2001, and was open to everyone. Workers in public and private agencies and non-governmental organizations were especially invited to attend. The topics addressed in the course fell under the following three general headings:

1. Coastal geology, coastal hazards, coastal management;
2. Coral reef ecology and stressors; and
3. Groundwater exploration and development.

The course consisted of 2.5 days seminar style lectures with discussions, 1.5 days field excursion, and 0.5 day wrap-up and final discussion. The complete course schedule appears later in this report.

Classroom sessions were held on the St. Thomas campus of the University of the Virgin Islands. In these sessions, presenters' lectures were supplemented with examples from their experiences in Puerto Rico and other locations in the Caribbean. Handouts, slides, videos and computer projections were used as tools in the lectures.

Field trips to sites of relevance around the island were used to reinforce the lectures. The trips consisted of lectures on site and demonstrations but also were structured so that application of methods described in class could be practiced.

Course participants were provided with packets of material to support the information presented in the lectures and the field trips. In addition, a website was created as further support for the course while it was being offered and for future reference by course participants and others. The site contains copies of reprints and Power Point slide shows used in the course and additional information that might not have been presented during the course. The site may be accessed at: http://www.westga.edu/~dbush/USVI2001/webfiles/index.htm.

Short Course Instructors

David M. Bush, Ph. D., P.G., State University of West Georgia

Dr. David Bush is Associate Professor of Geology at the State University of West Georgia in Carrollton, GA. He received his B.S. in Geology from the State University of New York, College at Oneonta, and both his M.S. and Ph.D. in Geology from Duke University. His graduate research focused on the sediments and storm processes along the northern Puerto Rico shelf and shoreline. He was a post-doctoral Research Associate with the Program for the Study of Developed Shorelines at Duke University for four years. It was then his research focused on coastal hazards, risk assessment mapping, and property damage mitigation. He has experience

with the U.S. Atlantic and Gulf of Mexico coasts, the Bahamas, and the Caribbean, including Puerto Rico, Dominican Republic, St. Lucia, Antigua and Barbuda, Honduras, Yucatán Peninsula of Mexico, Colombian Caribbean coast, and the U.S. Virgin Islands. He was part of the National Academy of Sciences post-disaster field study teams after Hurricanes Gilbert and Hugo. He was involved with planning the U.S. Decade for Natural Hazard Reduction, and is the senior author of *Living with the Puerto Rico Shore*, *Living by the Rules of the Sea*, and *Living on the Edge of the Gulf: The West Florida and Alabama Coasts*, plus several peer-reviewed journal articles dealing with coastal hazards, risk assessment, and property damage mitigation. Dr. Bush serves on the editorial board of *Environmental Geosciences*. At West Georgia Dr. Bush teaches courses in risk assessment, geomorphology, and oceanography, and has published numerous papers on hurricane impacts and coastal hazards of developed shorelines.

Robert S. Young, Ph. D., Western Carolina University

Dr. Robert Young is an Assistant Professor of Geology at Western Carolina University in Cullowhee, North Carolina. He received a BS in Geology from the College of William and Mary, an MS in Quaternary Studies from the University of Maine and he was a James B. Duke Doctoral Fellow at Duke University where he received a PhD in Geology. Dr. Young serves on the editorial boards of the *Journal of Coastal Research* and *Environmental Geosciences*. He is currently the Technical Program Director for the Geological Society of America's Annual Meeting. Dr. Young's research interests lie in a wide variety of coastal and wetland areas. He has been working in the area of coastal hazards, coastal storm processes, and coastal planning for the last ten years. This work has been focused on the U.S. East Coast, the Caribbean, and in Central America with funding from FEMA, The Natural Hazards Center, New Hampshire Office of Emergency Management, and the National Science Foundation. During this time, he has conducted post-storm reconnaissance after the impact of nearly every major hurricane to strike the U.S. mainland and several in the Caribbean. He has written numerous professional papers dealing with coastal processes, numerical modeling, risk mapping, and property damage mitigation.

Randall L. Kath, Ph. D., P.G., State University of West Georgia

Randy Kath is Associate Professor of Geology, Center for Water Resources, State University of West Georgia, 6 years teaching and research; 11 years geological and geological engineering consulting; 3.5 years gold exploration; Registered Professional Geologist: PR, GA, TN; 13 years of attempting to understand the hydrogeology of igneous and metamorphic rocks; Doctor of Philosophy in Geology, Institute for the Study of Mineral Deposits, South Dakota School of Mines and Technology.

Short Course Topics

Offshore Coastal Zone Evaluation and Monitoring (Rob Young)

Monitoring the physical aspects of the coastal system is a critical part of any proposal to monitor potential reef/nearshore ecosystem degradation. Changes in the nearshore physical parameters are the link between terrestrial land use and the offshore impacts to coral reef health. Without direct measurement of coastal sediment dynamics, water quality, and coastal erosion, one cannot directly relate reef degradation to the onshore land use changes that may be harming the reef. Most monitoring efforts in reef ecosystems have focused on biological monitoring of reef change, possibly combined with some water quality measurements. These studies neglect the extremely important role that erosion and sediment loading of the coastal zone can play in

raising turbidity levels and burying coral. Without vigorous coastal sediment transport monitoring along with the water quality analysis, reef harm from land clearing and vegetation removal cannot be separated from reef harm due to nutrient loading; and thus, proper management strategies to protect the reef ecosystem cannot be developed.

In order to preserve the valuable coral reef ecosystem during ecotourism development, we need to be able to link watershed level studies of land use directly to reef impact. This way we can determine whether reef degradation is due to increased sediment input or something like septic leaching, and by establishing this link, we may be able to institute management measures that will reduce the harm being done in time to preserve to resource we are all interested in preserving, the coral reef ecosystem.

Three important aspects of the offshore coastal zone must be evaluated:

1) The nearshore sediment cover and the amount of sediment in the water column. Numerous offshore study sites are established where three factors will be quantified: the average local thickness of sediment, the areal coverage of coral reef by sediment, and the turbidity of the water column.
2) At each of the above-mentioned sites, samples are taken for water quality analysis.
3) In addition, a detailed survey of the islands entire shoreline is made on foot and from the air. This survey catalogs shoreline type, degree of erosion (if any), beach width, vegetation cover, etc., using a geoindicator methodology developed for use in the Caribbean (Young et al., 1996; Bush et al., 1999–see below). This aspect is important to quantify any potential changes in coastal erosion or vegetation that may eventually impact reef viability.

All sites and surveys are located and recorded using GPS and entered into a GIS database for future reference and in order to relate these factors directly to a GIS database of land use and watersheds allowing determination of the focal point of any problems. This work can be carried out without the need for expensive or sophisticated field equipment. Initial monitoring stations and data collection are done with student assistance and local participants so that the methodologies are established and the bugs are worked out. After three years the program could be turned over to a local group for continued monitoring. All work can be carried out by divers/snorkelers working from a small boat.

Coastal Hazards and Risk Mapping (David Bush)

A Geographic Information System (GIS) is used to produce maps showing zones of relative risk of coastal storm damage for each study area. Applying GIS technology to hazard assessment and risk mapping along coastal areas, particularly barrier islands, benefits the communities by providing a basis for zoning, land use planning, and allocation of resources for post-storm property reconstruction and pre-storm damage mitigation plans. GIS may also be used to map and assess property damage or usefulness of attempts to protect and preserve coastal resources so that successful attempts may be continued and unsuccessful attempts abandoned. Such applications of GIS may ultimately lead to quantified assessments of ideal construction sites with areas of high risk left in a natural state--thus saving money and, possibly, lives.

Coastal risk mapping considers geography, geologic processes, and storm characteristics, all of which control the property damage potential of an island. Risk involves two components: hazards and vulnerability. Hazards are the physical processes of storms (wind, waves, surge) and vulnerability is the built environment which is subject to the storm physical processes (houses, other buildings, infrastructure, utilities). Observations made after several recent hurricanes and winter storms indicate that elevation and exposure to wind are the two primary factors controlling property damage. Secondary factors include dunes, vegetation, erosion rates, engineering, development, and historic storm response.

The goal of this project aspect of the workshop was to apply GIS technology to coastal risk mapping in terms of designating zones of relative risk for property damage during a moderate category 3 hurricane or equivalent strength winter storm. Coastal risk mapping is ideally suited to the application of Geographic Information System (GIS) computer technology. Island physical and geomorphic (landform) descriptive criteria are entered into a computer database, then, using GIS, any set of criteria can be combined to make risk assessments. The preliminary analysis can be made by GIS summing of elevation and forest cover digitally entered as separate layers. The secondary factors for revising the preliminary map can be added each as a separate digital layer, or summed separately depending on the users needs. When assessing potential coastal risk areas, zones are determined based on the above criteria, and an island divided into four categories designated as "Extreme Risk," "High Risk," "Moderate Risk," or "Low Risk" of property damage from hurricanes or other coastal storms.

Geoindicators (David Bush, Rob Young)

Coastal areas are at risk from such natural hazards as coastal erosion, storm-surge flooding, overwash, wind, dune loss, and human-induced problems (sand supply loss, increased erosion, loss of critical systems and water resources). The frequency, intensity, and location of active physical processes (or hazards) are controlled by *regional factors* (such as seismic setting and latitude), *local factors* (such as protective offshore barriers and coastal configuration), and *site-specific factors* (such as site elevation and vegetation). These factors, or *geoindicators*, provide clues to a coastal site's natural history and associated potential natural hazard risk.

When geoindicators are evaluated in a logically ordered checklist, shoreline erosion, potential coastal hazards and risks can be easily evaluated. This technique has wide application, spanning the range from an instructional tool to sophisticated coastal assessments on which to base coastal management policy. Further, the method fills a need for a scientifically valid method of qualitative shoreline assessment, given the reality of money and data shortages.

A geoindicators methodology will be applied to each study site, to evaluate shoreline change and coastal risk. The geoindicator approach is an outgrowth of recent experience in coastal hazard mapping, risk assessment, and property-damage mitigation studies summarized in Young *et al*. (1996) and Bush *et al*. (1999). National initiatives to develop coastal tourism potential carry the prospects for rapid, unsafe development, and need quick, reliable assessments of coastal-zone processes and associated hazards.

Geoindicators are defined by the International Union of Geological Sciences as "measures of surface or near-surface geological processes and phenomena that vary significantly over periods of less than 100 years and that provide information that is meaningful for environmental assessment" (Berger, 1996, p. 5). Geoindicators have a variety of management applications including environmental auditing and monitoring. In the coastal zone, shoreline change (usually erosion), risk/hazard assessment, and property damage mitigation are of primary concern. Although highly-sophisticated, high-technology environmental monitoring and historical analysis techniques are available as a means of collecting baseline data for coastal-zone management and policy determinations, these techniques are frequently expensive, time consuming, and require a high level of expertise. The geoindicator approach provides a viable, low-cost alternative.

The geoindicators approach identifies a minimum set of parameters that describe short-term environmental dynamics, and are proxies representing all the parameters on which processes depend (Berger, 1997). As a result, geoindicators can provide managers with simple, qualitative tools for rapid identification of coastal property damage risk potential that is scientifically valid. High precision isn't necessarily a requisite for coastal management decision-

making. Applying a checklist of local-scale geoindicators provides a quick, inexpensive, practical evaluation of shoreline change along any particular stretch of shoreline. A simple photographic record taken at each site is an easy way to begin documenting changes as well as to allow re-evaluation of the surveyor's characterizations.

The risk setting changes frequently in the setting of coastal communities, subject to both natural and human processes that alter environmental stability. Use of geoindicators can provide rapid updates of management and mitigation plans. In many cases, especially in developing countries where funds are limited and adequate historical shoreline position data is frequently lacking, the coastal manager, planner, or scientist can attain an immediate assessment of coastal risk/hazards from geoindicators. In such cases, long-term state-of-environment and monitoring projects should be initiated, but such studies often take years to provide useful information.

Groundwater Exploration and Development in Volcanic Island Arcs (Randy Kath)

Exploration for, and development of, groundwater in deformed volcanic island arc rocks in regions with a sub-tropical weathering environment have been little studied, and are poorly understood. Much of the funded research and many of the recent and current studies in this regard seem to focus on the physics of groundwater movement in *fractured* rock. During the last several decades these studies have been driven by environmental containment and remediation problems and concerns. For this, the objectives and goals are quite different from that required for exploration and development of groundwater as a resource, where the quantity, quality, and sustainability of the resource is of utmost importance.

Thirty years of exploration and development of groundwater resources in igneous and metamorphic rocks of the southeastern United States, where older deformed and metamorphosed volcanic island arcs are exposed, has convinced us that, among the many factors that influence groundwater in these rocks, the *single most important factor is rock type*. Rock type directly influences all other parameters, i.e., type of weathering, depth of weathering, and topography. Without knowing the *detailed* geology of an area/site, all other factors influencing groundwater lack a full and meaningful context.

For success in groundwater exploration and development in areas of exposed volcanic rocks, more than an understanding of the physical parameters controlling groundwater movement is necessary. The interrelationships, both inherent and spatial, of rock type, structure, type and depth of weathering, and topography must be known and understood. Because the occurrence of groundwater does not rely on any single factor and because each of these factors will vary, groundwater exploration and development data in volcanic rocks must be site specific.

Current models that have been applied to volcanic arc rocks along the southern margin of Puerto Rico have assumed that groundwater occurs in the alluvium and fractured and weathered volcanic rocks, Graves (1992). Because the smaller, modern volcanic islands generally do not contain extensive areas of alluvial aquifers, groundwater exploration and development must focus on the weathered and fresh bedrock aquifer systems. The bedrock aquifer system can be divided into a fresh-rock, transition zone, and regolith aquifer system. The regolith- and transition-zone systems contain the same parent rock as the fresh bedrock aquifer, but differ in that it is highly fractured, shattered, and variably weathered. These aquifer systems are generally shallow and susceptible to droughts.

The deeper fresh-rock aquifer system is drought resistant. Because these rocks have no primary porosity or permeability, locating groundwater requires that zones of secondary porosity and permeability in the subsurface be located as precisely as possible. To accomplish this, a good understanding of the site-specific geology is of utmost importance.

The exploration and development approach outlined by Crawford and Kath (2000) has

been very successful in exploration and development of groundwater resources in igneous (deformed volcanic arcs) and metamorphic rocks. Well yields using this exploration and development approach typically range from about 50 gpm to over 600 gpm in unique geologic settings. This approach begins with detailed site-specific geologic mapping to identify: rock type(s); discontinuities, due to compositional differences (layering) and fractures (joints and/or faults); topography; type and depth of weathering; nature and extent of the recharge area; and the spatial relationships of rock types and discontinuities to topography, type and depth of weathering, and recharge area.

The focus of this aspect of the course was on the team's experience with exploring for, and developing, groundwater resources. The exploration methods that were presented were directly applicable to many volcanic island arc systems.

Literature Cited

Aquirre, Benigno. E. and Bush, David M., 1992, Disaster Programs as Technology Transfers: The Case of Puerto Rico in the Aftermath of Hurricane Hugo: International Journal of Mass Emergencies and Disasters, v. 10, n. 1, p., 161-178.

Berger, A. R., 1996. The geoindicator concept and its application: an introduction. In *Geoindicators: assessing rapid environmental changes in earth systems*, ed. Antony R. Berger and William J. Iams, 1-14. Rotterdam: A. A. Balkema.

Bush, David M., 1991, Impact of Hurricane Hugo on the Rocky Coast of Puerto Rico, (in) Finkl, Charles W., and Pilkey, Orrin H., (eds.), Impacts of hurricane Hugo: September 10-22, 1989, Journal of Coastal Research, Special Issue #8, p. 49-67.

Bush, David M., Bruce R. Richmond, and William J. Neal, 2001. Coastal-zone Hazard Maps and Recommendations: Eastern Puerto Rico, *Environmental Geosciences*, 8(1), in press.

Bush, David M., Orrin H. Pilkey, and William J. Neal, 1996. *Living by the Rules of the Sea*, Durham, North Carolina: Duke University Press, 179 p.

Bush, David M., William J. Neal, Robert S. Young, and Orrin H. Pilkey, 1999. Utilization of Geoindicators for Rapid Assessment of Coastal-hazard Risk and Mitigation, *Ocean and Coastal Management*, vol. 42, no. 8, p. 647-670.

Bush, David M., Webb, Richard M. T., González Liboy, José, Hyman, Lisbeth, and Neal, William J., 1995. *Living With the Puerto Rico Shore*, Durham, North Carolina and London: Duke University Press, 193 p.

Crawford, T.J., and Kath R.L., 2000, Groundwater Exploration and Development in Igneous and Metamorphic Rocks: Part I Influencing Factors and Considerations: Drought 2000: Policy, Impacts, and Technology: V 1, N 1.

Graves, R.P., 1992, Geohydrology of the Aguirre and Pozo Honds Areas, Southern Puerto Rico: US Geological Survey Water Resources Investigations Report 91-4124.

Pilkey, Orrin H., William J. Neal, Stanley R. Riggs, Craig A. Webb, David M. Bush, Deborah F. Pilkey, Jane Bullock, and Brian A. Cowan, 1998. *The North Carolina Shore and Its Barrier Islands: Restless Ribbons of Sand*, Durham, North Carolina: Duke University Press, 318 p.

Pilkey, Orrin H., Jr., David M. Bush and Rafael W. Rodríguez, 1988, Carbonate-terrigenous sedimentation on the north shelf of Puerto Rico, (in) Doyle, L. J. and Roberts, H. H. (eds.) Carbonate-Clastic Transitions: Developments in Sedimentology, v. 42, Amsterdam: Elsevier, p. 231-250.

Rodríguez, Rafael, W., Webb, Richard M. T., and Bush, David M., 1994, Another Look at the

Impact of Hurricane Hugo on the Shelf and Coastal Resources of Puerto Rico, USA: Journal of Coastal Research, vol. 10, no. 2, p. 278-296.

Thieler, E. Robert, Bush, David M., and Pilkey, Orrin H., Jr., 1989, Shoreline Response to Hurricane Gilbert: Lessons for Coastal Management, (in) Magoon, O. T., el al., (eds.) *Coastal Zone '89*, Proceedings of the Sixth Symposium on Coastal and Ocean Management. New York: American Society of Civil Engineers, p. 765-775.

Thieler, Edward Robert and Bush, David Michael, 1991, Hurricanes Gilbert and Hugo Send Powerful Messages for Coastal Development: Journal of Geological Education, v. 39, p. 291-99.

Young, Robert S., Bush, David M., Pilkey, Orrin H., and Neal, William J., 1996, an Inexpensive Approach for the Qualitative Evaluation of the Shoreline Change Geo-indicator and Associated Risk from Coastal Hazards, (in) Berger, A.R. (ed.), Geological Indicators of Rapid Environmental Change. Rotterdam: A.A. Balkema, p. 193-206.

Reprints Provided–USVI 2001

Copies of several reprints on topics relevant to the course were provided to all participants.

Bush, David M., 1991, Impact of Hurricane Hugo on the Rocky Coast of Puerto Rico, (in) Finkl, Charles W., and Pilkey, Orrin H., (eds.), Impacts of hurricane Hugo: September 10-22, 1989, Journal of Coastal Research, Special Issue #8, p. 49-67.

Bush, David M., 1994, Coastal Processes, In: National Research Council, Hurricane Hugo: Puerto Rico, the Virgin Islands, and Charleston, South Carolina, September 17-22, 1989. Washington, DC: National Academy Press, National Academy of Sciences, Natural Disaster Studies Volume Six, p. 130-154.

Bush, David M., Neal, William J., Young, Robert S., and Pilkey, Orrin H., 1999. Utilization of Geoindicators for Rapid Assessment of Coastal-hazard Risk and Mitigation, *Ocean and Coastal Management*, vol. 42, no. 8, p. 647-670

Bush, David M. and Pilkey, Orrin H., 1994, Mitigation of Hurricane Property Damage on Barrier Islands: A Geological View, In: Finkl, C. W., Jr., (ed.), Coastal Hazards: Perception, Susceptibility and Mitigation, Journal of Coastal Research Special Issue No. 12, p. 311-326.

Bush, David M., Richmond, Bruce R., and Neal, William J., in press. Coastal-zone Hazard Maps and Recommendations: Eastern Puerto Rico, *Environmental Geosciences*.

Emery, K.O., 1961. A simple method of measuring beach profiles. *Limnology and Oceanography*, vol. 6, p. 90-93.

Hickey, R., D. Bush, and R. Boulay, 1999, GIS Applications in Coastal Risk Assessment. *Cartography*. v. 28, no. 2, pp. 11 - 19.

Pilkey, Orrin H., Jr., and E. Robert Thieler, 1992. *Coastal Erosion*. Text accompanying Society of Economic Paleontologists and Mineralogists (SEPM) Slide Set No. 6, 24 p.

Rodríguez, Rafael, W., Webb, Richard M. T., and Bush, David M., 1994, Another Look at the Impact of Hurricane Hugo on the Shelf and Coastal Resources of Puerto Rico, USA: Journal of Coastal Research, vol. 10, no. 2, p. 278-296.

Thieler, Edward Robert and Bush, David Michael, 1991, Hurricanes Gilbert and Hugo Send Powerful Messages for Coastal Development: Journal of Geological Education, v. 39, p. 291-99.

Young, Robert S., David M. Bush, Andrew S. Coburn, Orrin H. Pilkey, and William J. Cleary, 1999. Hurricanes Dennis and Floyd: Coastal Effects and Policy Implications, *GSA Today*, vol. 9, no. 12, p. 1-6.

Books/Videos/Reports–Display Copies Only

Sample copies of books, brochures, videos, and other publications were on display during the course.

Books:

Beatley, Timothy, David J. Brower, and Anna K. Schwab, 1994. *An Introduction to Coastal Zone Management*. Washington DC: Island Press, 210 p.

Bush, David M., and Pilkey, Orrin H., 1996, *Living by the Rules of the Sea*. Durham, North Carolina and London: Duke University Press, 179 p.

Bush, David M., Webb, Richard M. T., González Liboy, José, Hyman, Lisbeth, and Neal, William J., 1995. *Living With the Puerto Rico Shore*, Durham, North Carolina and London: Duke University Press, 193 p.

Kaufmann, Wallace and Orrin H. Pilkey, Jr., 1983. *The Beaches are Moving: The Drowning of America's Shoreline*. Durham, North Carolina: Duke University Press, 336 p.

Lennon, Gered, Neal, William J., Pilkey, Orrin H., Bush, David M., Stutz, Matthew, and Bullock, Jane, 1996. *Living With the South Carolina Coast*, Durham, North Carolina and London: Duke University Press, 241 p.

Pilkey, Orrin H., William J. Neal, Stanley R. Riggs, Craig A. Webb, David M. Bush, Deborah F. Pilkey, Jane Bullock, and Brian A. Cowan, 1998. *North Carolina and It's Barrier Islands: Restless Ribbons of Sand*. Durham, NC: Duke University Press, 318 p.

Videos:

The Beaches Are Moving
Living on the Edge
The Vanishing Lands

"Living With the Shore" books and all videos available from:

Environmental Media Corporation:
1102 11th Street
Port Royal, SC 29935 -2304
800.368.3382/843.986.9034 Voice
843.986.9093 Fax
email: bpendergraft@envmedia.com
http://www.envmedia.com/

Government Reports:

Williams, S. Jeffress, Kurt Dodd, and Kathleen Krafft Gohn, 1990. *Coasts in Crisis*. United

States Geological Survey Circular 1075, 32 p.

Federal Emergency Management Agency, 1999, Hurricane Georges in Puerto Rico: Observations, Recommendations, and Technical Guidance. FEMA Building Performance Assessment Report, FEMA publication FEMA-339, March 1999.

Coastal Management Solutions to Natural Hazards, 1990, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Ocean and Coastal Resource Management, Coastal Programs Division Technical Assistance Bulletin #103, 50 p.

Federal Emergency Management Agency Publications Catalog.

Course Schedule

Monday July 16--*Course Begins, full day of lectures*

morning: Opening and Lectures

-Opening greetings and remarks ***(½hr)***
-Introduction of personnel
-Introduction of participants
-Lecture: Multiple Coastal Hazards Mapping: The Puerto Rico Experience (Dave Bush) ***(1.5 hr, including discussion)***
-Lecture: Abiotic Monitoring of the Coastal Zone in the Bay Islands, Honduras (Rob Young) ***(1.5 hr, including discussion)***

afternoon: Lectures and Video

-Lecture: Impact of Erosion and Sediment Loading on Coral Reef Vitality (Rob Young) ***(1 hr, including discussion)***
-Video and discussion: *Selected parts of coastal videos* ***(1 hr)***
-Video and discussion: *VI Non-Point Source Pollution* ***(1 hr)***

Tuesday, July 17: *lectures and field trip*

morning: Lectures

-Lecture: Coastal Hazards, Risk Assessment, and Property Damage Mitigation (Dave Bush) ***(1.5 hrs, including discussion)***
-Lecture: Monitoring Shoreline Change (Rob Young) ***(1.0 hrs, including discussion)***
-Video and discussion: *Beach Profiling Training Video* ***(15 minutes)***
-Introduction to field trip: Geoindicators Assessment of Shoreline Change, Coastal Risk Mapping, Beach profiling

afternoon: field trip

-coastal problems

Wednesday, July 18: *full day of lectures*

Groundwater Exploration and Development in Volcanic Island Arcs

Thursday, July 19: ***full day field trip***

-groundwater exploration and development

Friday, July 20: ***Course Conclusion***

morning: discussion

-closing discussion by all participants
-create list of site-specific problems
-end of course