Understanding And Managing Karst Water Resources In Belize: Case Studies Of Both Past And Present In A Changing Climate

National Cave and Karst Research Institute

UNDERSTANDING AND MANAGING KARST WATER RESOURCES IN BELIZE: CASE STUDIES OF BOTH PAST AND PRESENT IN A CHANGING CLIMATE

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Abstract

Belize is a developing country that faces water resource issues in the forms of both quality and quantity, stemming from a long history of environmental stress and population threats, from the ancient Maya to present. Belize's karst landscape, which comprises a large part of the country from the coast to the Maya Mountains, is characterized by springs, caves, sinkholes, and aquifers systems formed from the dissolution of carbonate (limestone, dolomite) rock. This research presents several different case studies, spanning from the ancient Maya and issues with drought to modern communities that rely on groundwater resources quickly being depleted. Past drought patterns may recur, and their effects on population and the environment in areas like Orange Walk in the north to Gales Point in the south, where villages and towns surrounded by karst remnants have limited access to fresh, clean water. Part of this research used cave sediments to examine past vegetation change and the impacts of the Maya on the landscape on the Vaca Plateau to provide a history of socio-environmental interactions. We also examined the modern water resource issues for Belize, and have several pilot projects underway throughout the region to study and resolve these issues and compare the modern population to that of the Maya to better understand issues from future drought and climate change.

Introduction

Belize is a developing country that faces water resource issues in the forms of both quality and quantity. Part of this stems from a long history of drought and climatic change resulting in environmental stress and threats to populations, from the ancient Maya to present. Belize's karst landscape, which comprises a large part of the country from the coast to the Maya Mountains in the west, is characterized by springs, caves, sinkholes, and aquifers systems formed from the dissolution of

carbonate (limestone, dolomite) rock (Figure 1). This environment provides substantial groundwater resources. These significant karst landscapes are susceptible to development, pollution, and agricultural impacts, as well as overpopulation. The country has 39 watersheds, 18 of which are considered to be major watersheds such as rivers, streams and groundwater aquifers. The country's major economic drivers are tourism and agriculture, both of which rely heavily on Belize's natural resources (Barnett et al. 2011). Although agriculture is second to tourism economically, the government of Belize has identified the improvement and expansion of agriculture as one of the principal aims of national development planning. This research presents several different case studies, spanning from the ancient Maya and examining past drought issues and their effects on population and the environment, to modern Belize, in areas like Orange Walk in the north and Gales Point in the south. These communities subsist on agricultural and community wells that are going dry, and suffer from water quality issues. In Gales Point, where a village of 500 people live on a peninsula in a lagoon surrounded by karst remnants and whose access to fresh, clean water is limited by several environmental and social issues, this is especially problematic. There is also a need for improved water quality monitoring and testing, as the karst landscape provides little filtration in most areas, and the rural communities in particular rely on wells or springs for their water supply, which often are contaminated by agricultural pollutants, or when they are unusable cause people to turn to inadequate water sources to survive.

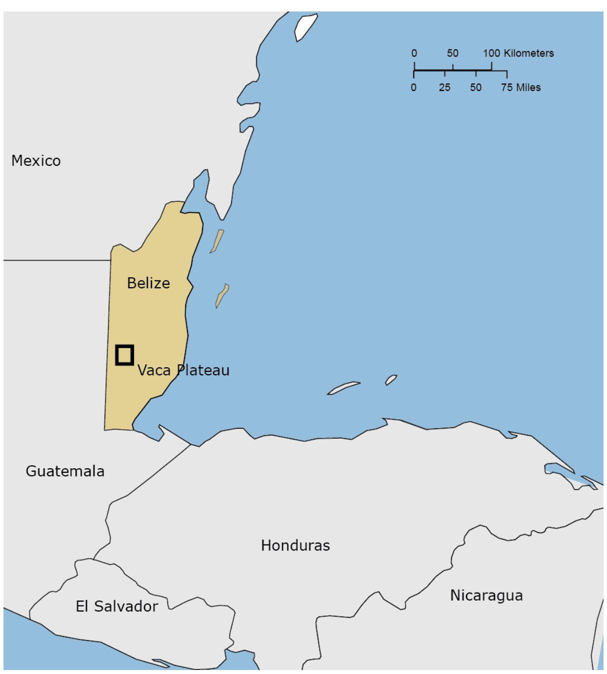

Figure 1. *Map of study area.*

Study Area

Belize, a subtropical country, experiences a dry season from December to May and a wet season from June to November. The mainland's topography consists of a mountainous, forested southern region and a flat northern region. In the peak rainfall month of July Southern Belize receives on average 70 cm of rain while for the same month the northern part of the country receives on average less than 25 cm. The Maya mountains found in the southern part of the country are composed of unmetamorphosed to slightly metamorphosed late Palaeozoic sedimentary rocks and granitic intrusions, while the northern, western and southern flanks of the mountains are flat-lying Cretaceous limestones. The northern part of Belize is a complex of Tertiary limestones and marls with many shallow closed-depressions, and Quaternary alluvial deposits, and swamps (James and Ginsburg 1979; Miller 1996) underlain by the flat lying carbonate deposits of Cenozoic age.

Methods

Recent studies have sought to better understand the socio-environmental dynamics of the Maya civilization in Belize, and since 2004 research in the north Vaca Plateau has focused on using geological proxies for reconstructing local and regional paleoenvironmental conditions. Since 2007, studies using cave deposits from the Vaca Plateau have proven to be effective in delineating periods of climatic and land use change sequences that help explain the waning of the Maya population in the area (Polk et al. 2007). To further refine the paleoenvironmental information that is already known about the study area, several lines of investigation were initiated in 2010 involving geoarchaeological field reconnaissance, and sampling of cave sediments and carbonate deposits to compliment the developing archaeological record. The primary research area focuses on the Minanha and Lower Dover archaeological sites. During two field seasons (2010, 2012), eight sediment core samples from caves in the study area near the Lower Dover and Minanha sites were collected (Figure 2, 3). Currently, processing of the new sediment cores is underway for radiocarbon dating, with a focus on establishing a chronology of up to 3000 years. Work

Figure 2. *Collecting sediment cores from Box Tunich Cave (photo by Jason Polk).*

on these core samples involves analyzing the sediments for $\delta^{13}C$ data to understand land use change from past human-environmental interactions. A driving hypothesis is that the location of these Maya population centers were the first to be susceptible to increasing drought and environmental degradation because of the nature of the highly-drained, thinly mantled karst topography, leading to issues with access to water for agricultural purposes.

Similarly, many other modern communities living upon the fragile karst aquifers of the country are also currently suffering problems due to these same types of climate change and water issues. The community of Gales Point, existing on a small karst peninsula (Figure 4), has struggled with water access for decades, relying on a small well and pumping system, and sometimes from a spring-fed stream during the wet season. In the past decade, the well was drilled and a pump installed a few miles from the village and water is pumped to a storage tower. In recent years, flooding, hurricanes, and equipment issues have caused continued problems with the water supply, and water quality remains an issue.

In Gales Point, as well as in Orange Walk and Corozal in the north, we are working to study the effects of these climatic changes and karst groundwater issues on the community and their perception of water treatment efforts and availability. This is being completed using participatory needs assessments, water quality studies monitoring fecal coliform bacteria on a monthly basis, and an isotope hydrology study to determine storm variability, recharge characteristics, and groundwater flow patterns. The research includes community assessments regarding water resources, karst landscapes, and sustainability knowledge. It also entails methods to survey, delineate, and assess karst groundwater

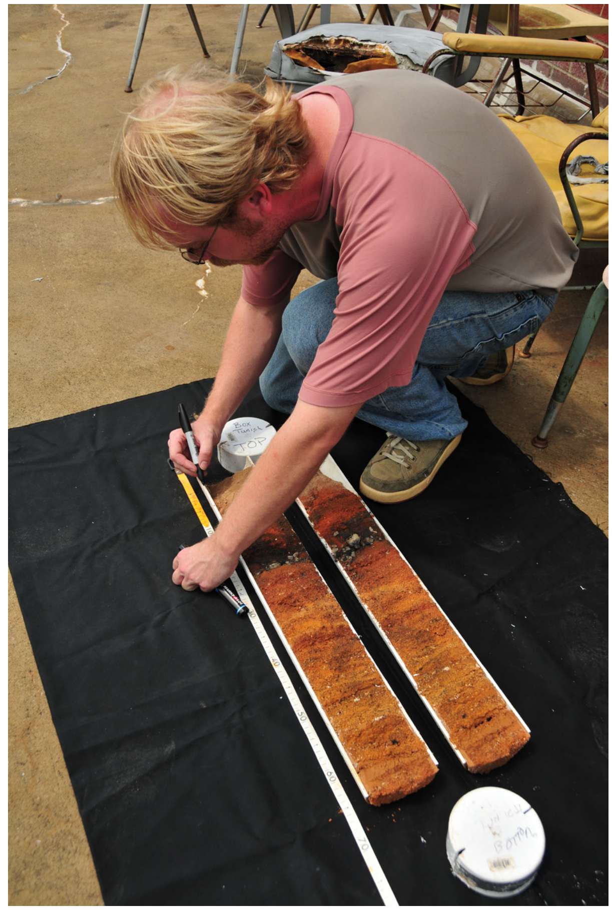

Figure 3. *Cutting and processing of sediment cores for carbon isotope analysis (photo by Jason Polk).*

sources, as well as developing water quality monitoring and outreach programs with partners to develop a comprehensive plan to address these issues.

Results and Discussion

As requested from the CARICOM Heads of Government, the Caribbean Community Climate Change Centre produced an Implementation Plan to guide the delivery of the 'Regional Framework to Achieving Development Resilient to Climate Change.' This plan identifies the regional strategies for coping with climate change and requires strategic action for the quantification and mapping of groundwater resources in the CARICOM Member States (Caribbean Community Climate Change Centre 2011). Throughout the wider Caribbean region, Global Climate Model-based rainfall projections under a 1° to 2°C increase in temperature are indicating a decline in annual rainfall and annual rainy days throughout the region (Nurse and Sem 2001; Solomon et al. 2007). The magnitude and extent of impact this will have on

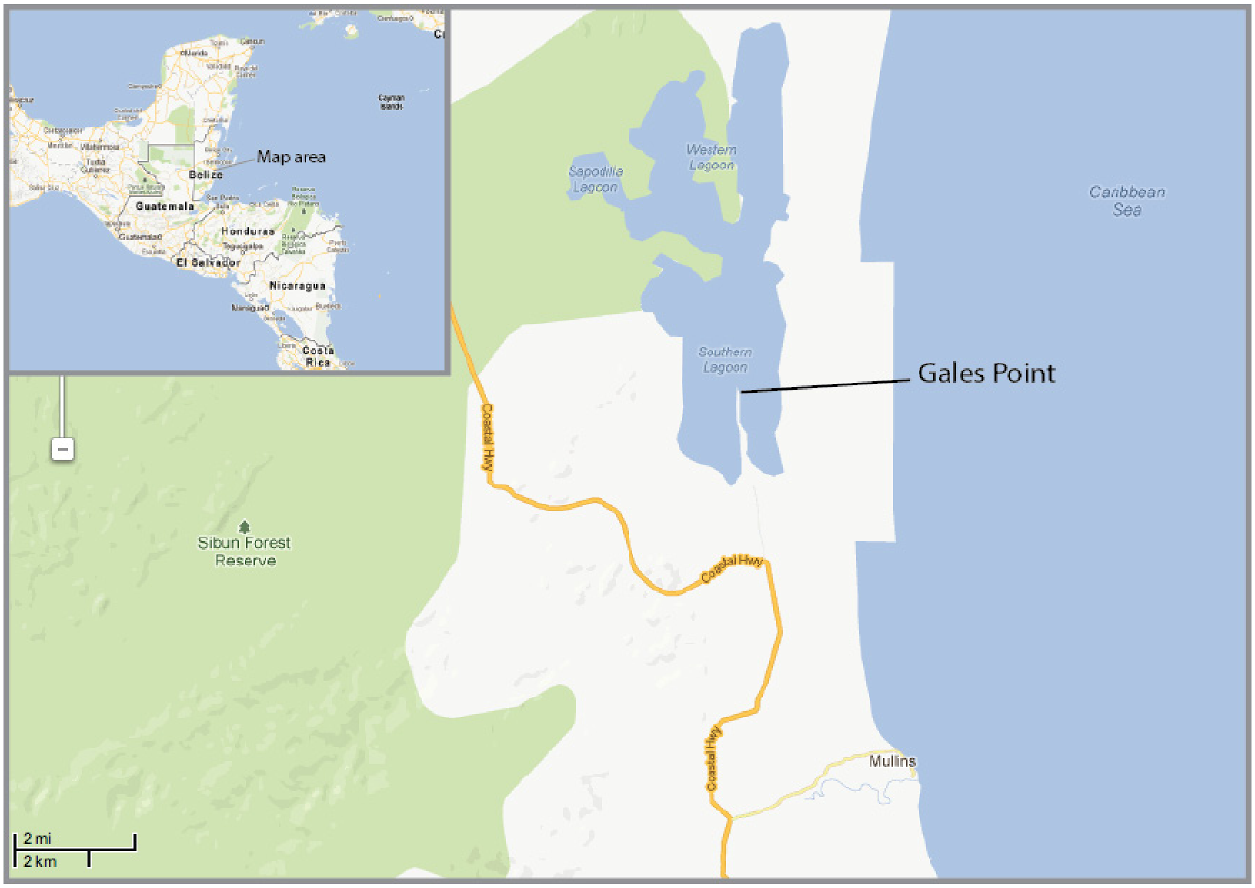

Figure 4. *Map of Gales Point, Manatee, a small karst peninsula jutting out into the lagoon (map modified from Google Maps).*

Belize's water resources is currently unknown. This lack of knowledge is detrimental to the development of Belize as groundwater is the main source of water for irrigation and serves as potable water in many rural areas of Belize. Just as with the ancient Maya in the past, the future is unknown as to how coping with a degrading environment, population growth, and water resource issues in the face of climate change will play out. With the country's vision of increasing agricultural earnings by increasing productivity, there is a projected increase in the consumption of water for agricultural purposes. This, coupled with the additional demand for water resources by a rapidly increasing population and the clearing of forested areas, will, with no doubt, diminish the country's available water resources per capita, much as it may have done to the ancient Maya civilization in the past (Figure 5).

The vulnerability of groundwater resources from climate change is of primary concern to developing countries, such as Belize, and is difficult to evaluate because technology, expertise, and data are currently lacking to accurately assess this climatic and socioeconomic threat (FAO 2000). The rapid increase in population and demographic spread, recent changes of land use, and the lurking threat of climate change are factors that can exacerbate the water deficit situation already being experienced in the northern portion of Belize (BEST 2008; BEST 2009). When groundwater abstraction rates exceed its sustainable yield, it can result in saltwater intrusion and drought; both are outcomes that can be further exacerbated by the potential impacts of climate change. With increased agricultural practices in Northern Belize and unknown aquifer recharge areas there is also a high risk in the contamination of groundwater resources by agrochemicals that can have human health implications.

The government of Belize has identified the expansion and improvement of agriculture as one of the principal aims of national development planning. In northern Belize, agriculture is a vital sector with 43% of all farms

Table 1: Physical description of the Box Tunich sediment core.

Depth (cm)	Color	Description
0-1	7.5YR 5/4	silty, poorly sorted
1-2	7.5YR 3/4	silty, poorly sorted
2-3	7.5YR 3/4	silty, poorly sorted, small quartz pebbles
3-4	7.5YR 3/4	silty, poorly sorted
4-5	7.5YR 3/4	silty, poorly sorted
5-6	7.5YR 5/3	silty, loose, some clay
6-7	7.5YR 5/3	silty, poorly sorted, some clay, small quartz pebbles
7-8	7.5YR 5/3	silty, loose, some clay, small bones fragments
8-9	7.5YR 5/3	silty, loose, some clay, small bones fragments
9-10	7.5YR 4/6	silty clay, some inclusions of 5YR 4/6 clay, tiny bone pieces
10-11	5YR 4/6	silty clay
11-12	5YR 4/6	poorly sorted, inclusions of 5YR 4/4, silty
12-13	5YR 4/6	silty clay, poorly sorted
13-14	5YR 4/6	poorly sorted silty clay
14-15	5YR 4/6	poorly sorted silty clay
15-16	5YR 3/6	some organics, silty clay
16-17	5YR 3/4	silty clay with some gravel
17-18	5YR 3/4	silty clay w/ Mg deposits
18-19	5YR 3/3	organic matter w/Mg deposits, charcoal rich
19-20	5YR 1/2	dark organic layer w/ Mg and Fe staining, thick calcite crystal deposit (flowstone?)
20-21	5YR 1/2	dark organic layer w/ Mg and Fe staining, thick calcite crystal deposit
21-22	5YR 1/2	dark organic layer w/ Mg and Fe staining, thick calcite crystal deposit
22-23	5YR 1/2	dark organic layer w/ Mg and Fe staining, thick calcite crystal deposit
23-24	5YR 1/2	dark organic matter, clay, bacterial residue
24-25	5YR 1/2	dark organic layer w/ Mg and Fe staining
25-26	5YR 1/2	dark organic layer w/ Mg and Fe staining
26-27	5YR 1/2	dark organic layer w/ Mg and Fe staining
27-28	5YR 1/2	dark organic layer w/ Mg and Fe staining
28-29	5YR 1/2	dark organic layer w/ Mg and Fe staining
29-30	5YR 1/2	dark organic layer w/ Mg and Fe staining
30-31	5YR 1/2	dark organic layer w/ Mg and Fe staining
31-32	5YR 4/6	clayey, some rounded quartz pebbles
32-33	5YR 4/6	sandy clay, some rounded quartz pebbles, clasts of 5YR 5/8
33-34	5YR 4/6	sandy clay, quartz pebbles, calcite flakes
34-35	7.5YR 5/6	sandy clay, quartz pebbles, calcite flakes
35-36	7.5YR 6/6	sandy clay, rounded, black quartz pebbles, limestone pieces
36-37	7.5YR 5/6	sandy clay, rounded, black quartz pebbles, limestone pieces
37-38	7.5YR 5/6	sand and quartz pebbles

Figure 5. *Example of sediment core variability, indicating changes in erosion and vegetation from climate change over time.*

located in that region of the country, and also one of the heaviest users of groundwater, while concurrently a potential source of pollution (Day 1996). Northern Belize experiences water deficit during the dry season, receiving approximately 130cm/year of rainfall, which is a third of the precipitation of southern Belize (Marfia 2004). This is a major concern as groundwater supplies about 95 percent of the rural population. Another major factor in water access and quality is the karst hydrogeology of this region, wherein water rapidly flows underground to aquifer systems, bringing with it possible contaminants, and even some sources disappear, as in the case of Five Blues Lake (Figure 6) (Day 1996; Day and Reynolds 2012). This also leads to a lack of surface water in the form of rivers or lakes, and creates problems in being able to easily and accurately predict groundwater recharge and flow patterns. Solutions to these challenges can be achieved through an improved understanding of groundwater system and recharge variability, an increased ability to manage water resources through planning, and an improvement in the capacity of local communities and the national University to maintain these efforts in the future. The project's main goal is therefore to ensure water security in the face of climate change through the capacity building of Belizeans and the generation of data necessary to produce a comprehensive water balance

Figure 6. *Five Blues Lake, located in central Belize, which is a karst feature that drained in a matter of days in 2012, and has done so several times. It serves as the nearby village's water supply (photo by Bill Reynolds).*

estimate for the vulnerable karst regions of the country of Belize. This can then be updated periodically as data are collected and technology and training are improved.

An example of successful outcomes is at Gales Point, where previous use of chlorination cause problems with locals misunderstanding the chemical taste and not wanting to use the water. Recently, thanks to support from the Merritt Island Rotary Club in Florida, a UV light filtration system was installed in the community school, which provides clean water continuously, with low-cost and maintenance, as a pilot project for the community (Figure 7).

In collaboration with the Belize Ministry of Health (water division) and Ministry of Rural Development, we are working on education programs and capacity building to implement this system in the community, as well as others in the country. We are also working with the University of Belize on a climate and water program related to this research, and with the CCCCC regarding a high-resolution climate model for Belize to better predict variability over the next century. Having a cultural understanding of past water issues facing populations like the Maya, and those living similar in regards to water access and quality, and natural resources, in the present, allows researchers to better address water resource problems in the country. This work involves cooperation with state and local governments, public officials, educators, and students to address these issues from a variety of angles, and help us learn about using the present and the past to live sustainably in karst regions.

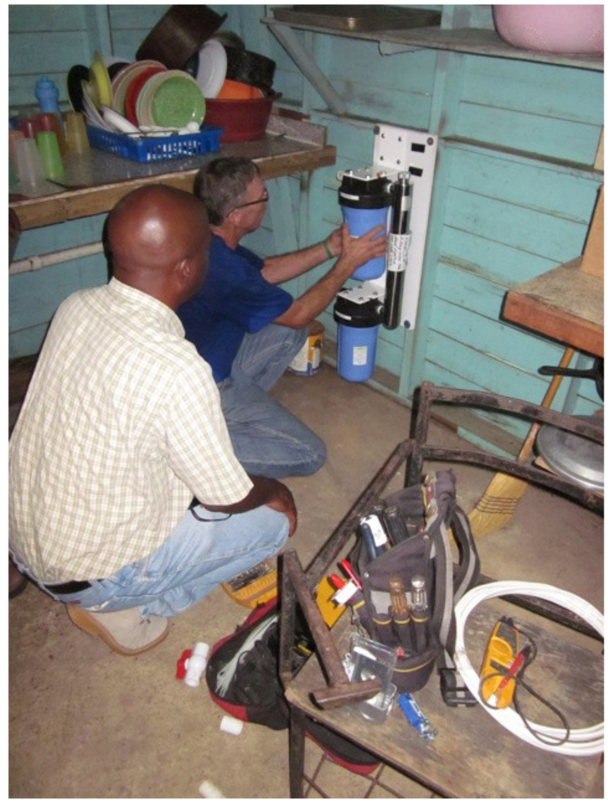

Figure 7. *AJ Strenecky of the Goshen Rotary and Mr. Anthony Flowers of the Ministry of Health inspecting the newly installed UV water purification system (photo by Jason Polk).*

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Biography

Jason S. Polk, Ph.D. is the Associate Director of Science for the Hoffman Environmental Research Institute and an Assistant Professor of Geography and Geology at Western Kentucky University. He earned his doctorate degree from the University of South Florida in Geography and Environmental Science and Policy, where his research focused on karst speleogenesis, climate change, and water resources. Dr. Polk's current research investigates the geomorphology and hydrology (including water quality) of karst environments, isotope geochemistry, karst resource inventory and management, and the influence of climate change on paleohydrology. He has published over 30 peer-reviewed papers and abstracts, is a Fellow of the National Speleological Society, and is Secretary of The Karst Conservancy. He is also a member of the Geological Society of America, American Geophysical Union, International Association of Hydrogeologists, and Association of American Geographers.