Impacts of Hurricane Mitch on Water Quality and Sediments of Lake Izabal, Guatemala

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Executive Summary

Aerial and ground surveys were conducted at Lake Izabal and Boca del Polochic to determine if impacts from Hurricane Mitch (October/November 1998) could be detected in wetland vegetation, water quality, or sediment stratigraphy. We sampled six water quality and eight sediment sites to assess impacts. Overall, we found no apparent evidence of Hurricane Mitch impact in the sediment cores or water quality. We found dissolved oxygen levels to be surprisingly good, and stratification in the water column was only shown at the offshore site. Sediment cores revealed multiple depositional layers, but nothing that could be obviously attributed to Hurricane Mitch. We were coring to a maximum depth of 60 cm, which may have been too shallow to observe the sedimentation event that occurred 2 years earlier as a result of the massive flooding reported during the storm. We observed peat layers at the mouth of the river, which probably delineated relatively normal weather events that had occurred over the past rainy season rather than older events. It seems that sedimentation and accretion processes in the delta are rapid; therefore, it is possible that our analysis was too late to detect any sedimentation event that would have occurred as result of Hurricane Mitch.

Background

Lake Izabal (Lago de Izabal; fig. 1) is the largest lake in Guatemala, 45 km in length, with an area of 590 km^2 and a maximum depth of about 17 m. It is an inland lake located in the eastern part of the country, not far (40 km) from the Caribbean coast. The lake is surrounded by mountains (Sierra de las Minas to the south, Sierra de Santa Cruz to the north) and is fed by many streams, the greatest of which is the Rio Polochic, one of the largest streams in the country. The outflow from the lake is via the Rio Dulce, through a smaller lake, La Golfette, and into Bahia de Amatique and the Gulf of Honduras near the town of Livingston.

Lake Izabal and the natural areas surrounding it are very rich in flora and fauna. The lake supports an important recreational and commercial fishery and serves as habitat for high-profile aquatic species such as tarpon (*Megalops atlanticus)*, sweet-water sharks (*Carcharhinus leucas*), and the endangered West Indian manatee (*Trichechus manatus)*. The wetlands and upland habitat adjacent to Lake Izabal provide habitat for hundreds of species of migratory birds as well as for mammals such as howler monkeys (*Alouatta pigra)*. Several biological reserves and areas of special protection have been established around Lake Izabal. Refugio de Vida Silvestre Bocas del Polochic is a Ramsar site that serves as a refuge for manatees and is a migratory bird staging area, and it is the second largest freshwater wetland area in Guatemala. Sierra de las Minas Biosphere Reserve south of the lake is the most important cloud forest reserve in Guatemala. El Biotopo de Chocon Machacas is a reserve adjacent to El Golfette, just downstream from Lake Izabal, that was established for manatee protection. The number of endangered manatees in the region is now believed to be less than 50, and they were most frequently observed in Lake Izabal, especially the southwestern portion of the lake near Boca del Polochic (Quintana Rizzo 1993, UNEP 1995). All of these features help make Lake Izabal and its environs one of Guatemala's most important natural areas for fishing, birding, and ecotourism.

Dix et al. (1999) studied nutrients and water quality in Lake Izabal and the lower Rio Polochic in 1998 and 1999. The study was ongoing when Hurricane Mitch impacted the region (October 28 through November 5, 1998), dropping more than 50 cm of rain in some parts of Guatemala and Honduras. Dix et al. (1999) found a significant spike in levels of total suspended solids (TSS), total phosphorus, total nitrogen, ammonium, nitrates, and fecal coliform counts at some of the sample sites in November 1998, immediately following Hurricane Mitch. These spikes were attributed to the tremendous increase in runoff carried by the Polochic and other tributary streams into the lake after the hurricane.

Because of Lake Izabal's importance to the regional ecology, we set out with the objective to assess whether impacts from Hurricane Mitch resulted in detrimental changes to the lake's water quality or to the integrity of wetlands associated with the Boca del Polochic, and to determine if a significant deposition of sediment could be detected in the stratigraphy of the Polochic River Delta sediments.

Methodology

Aerial reconnaissance of Rio Dulce, Lake Izabal, and associated wetlands of the Boca del Polochic were conducted in December 1999. Ground studies and additional aerial surveys were conducted in January 2001. During surveys we noted species of wetland flora and fauna. We established sampling sites for sediments (eight sites) and water quality (five sites) on the Polochic River Delta, either in wetlands or in the nearshore zone of the lake; one additional water quality sampling site was established in the lake's offshore zone. At each water quality site we used a Yellow Springs Instruments (YSI) oxygen/temperature meter to measure dissolved oxygen (DO) and temperature at various depths in the water column, and thus to construct a depth profile. This depth profile allowed us to test for stratification in the water column and for detrimental effects associated with nutrient enrichment and eutrophication. We used a 10-cm wide by 50-cm long PVC corer to retrieve sediment cores at each sediment site. The core was removed from the corer and placed on a flat surface for photodocumentation and observation. We examined each core externally and documented both sedimentary layers observed and their respective depths. We looked for signs of sediment depositions that could be associated with Hurricane Mitch. We then bisected each core along its longitudinal axis and performed similar measurements on internal sediments.

Results and Discussion

We found an extensive area of emergent fresh marsh and forested wetlands on the west end of Lake Izabal associated with the delta at the mouth of the Rio Polochic. Beds of floating and submersed aquatic vegetation were also present in Lake Izabal near the Polochic Delta. Aerial reconnaissance showed no observable physical damages to wetland vegetation in this region; wetlands appeared very healthy and plants seemed to be growing vigorously. During the overflights we did note extensive sedimentation in some areas of the lake bed that may have been associated with Hurricane Mitch.

Water Quality Observations

The Polochic River forms an elongated meandering delta (fig. 1) that stretches out into the lake and the water exits into the lake through two outlets. There is a northeast distributary (fig. 2) and a south distributary (fig. 3). The ground crew began analyses of water conditions at the northeast Polochic distributary channel. A heavy phytoplankton bloom was observed believed to be *Microcystis* sp. based on the colloidal or globular shape (John Burns, St. Johns River Water Management District, oral communication). An apparent increase in sediment load was observed in the river outflow and evidenced by increased visible water turbidity that increased with movement from distal to proximal location at the mouth of the river. This observation was confirmed from the air where a large sediment plume was observed exiting the mouth of the river from both the northeast and south outlets (see figs. 2 and 3). Sediment loads were proportional to the distribution of flow at each exit with the south exit being the greatest.

Site 1: Mouth of northeast Polochic River

At the mouth of the northeast Polochic River distributary a swift current was observed and the water column was turbid and completely mixed throughout (no apparent stratification), and the depth was estimated to be 4 m. No globular phytoplankton were visible in the immediate area, but the water had a green tint. Measured saturated dissolved oxygen concentrations were found throughout the well-mixed water column (table 1).

Site 2: Mouth of south Polochic River

At the mouth of the south Polochic River distributary channel, conditions were similar to what was observed at the northeast distributary, however, the volume of flow was much greater. We observed numerous deltaic “finger” formations throughout the area, which is indicative of large and active sediment deposits originating from the river. Some of these deposits were subaerial; they could have been deposited largely during episodic flood events. At this site we took water quality measurements at 20 cm depth in the water column (see table1).

Site 3: West of Polochic River

We traveled west of the Polochic River to a large interdistributary embayment area that was out of the direct influence of the Polochic River outflow. Samples (table 1) were taken off of a large point that was lined with various species of aquatic vegetation including predominately *Hydrilla verticillata* and to a lesser extent *Eichhornia*, *Ceratophyllum*, *Salvinia minima*, and *Nymphaea* sp. We also noted emergent plant species including *Cyperus* sp. and *Paspalum* sp. At this site we also were in hearing distance of howler monkeys (*Alouatta pigra*) in the adjacent trees.

Site 4: 300 m south of mouth of Polochic River

Water column profile analysis was performed to determine if there was any evidence of stratification occurring as a result of hyperproductivity at the outfall of the river. The rationale for these observations was the occurrence of heavy phytoplankton blooms that may have been indicative of high nutrient releases from the river to the lake and potential for eutrophication.

We chose an area approximately 300 m from the river mouth (site 4; table 2) and one at a distance of at least 1 km from the mouth (site 5; table 3) to determine the influence of the river on oxygen and temperature dynamics. At site 4 we observed water with a turbid green tint and a moderate phytoplankton bloom. We found no apparent stratification of temperature or dissolved oxygen at this site and, in fact, the site was thoroughly mixed. These observations were not surprising this close to the river.

Site 5: Approximately 1 km south of mouth of Polochic River

A second water column profile (table 3) was measured here to determine if there was a river effect, stratification, or evidence of eutrophic conditions. We observed clearer water here but also a very heavy algal bloom. This bloom is typical of heavy riverine nutrient output at a distance where sediments have largely settled out of the water column and the dissolved nutrients coupled with plentiful sunlight are conducive for heavy algal blooms. What also may occur under these conditions is oxygen supersaturation at the surface (because of phytoplankton photosynthesis) and in the later stages of the bloom a rapid dissolved oxygen depletion at the lower depths caused by respiration (oxygen consumption) of dying algae. We saw no evidence of oxygen stratification and, in fact, we recorded oxygen supersaturation as far as we could get the probe down. A strong current made it difficult to get the probe down more than 8 m but it was obvious that the current was also creating a holomictic condition in the water column. We therefore were unable to detect any stratification.

This area was obviously still heavily influenced by the river flow and, although we were unable to detect oxygen stress, it is likely that, during large phytoplankton dieoffs, significant oxygen depletion could occur. Since our time at the site followed the end of the rainy season (July-December), it may have been that we were sampling in a period of peak productivity that may be followed by respiration-dominated water column conditions and hypoxia during the subsequent low-flow period.

Site 6: Middle of Lake Izabal (January 18, 2001)

We sampled this site via amphibious aircraft access to profile at a point presumably completely out of reach of the direct influence of the river outfall. This site was approximately 10 km east of the mouth of the Polochic River. Here the water was also clear but green with a phytoplankton bloom evident.

We observed dissolved oxygen concentrations at the surface that were below saturation (table 4). We also found greater stratification in DO (but not temperature) below 5 m. This stratification is consistent with our thinking that greater stratification and potential eutrophic effects of high nutrient output may have been more prevalent in areas farther from the immediate reaches of the river outflow. Overall, however, the values we measured in the lake were encouraging and certainly in this snapshot analysis we did not see any definitive evidence of either deteriorating conditions or negative impacts that may have been a result of large storm events such as Hurricane Mitch. Jorge Cordona (Director, Refugio de Vida Silvestre Bocas del Polochic, written communication) informed us that the lake has a turnover of once every 6 months, which would make nutrient accumulation and associated negative impacts less common. This turnover could also explain the lack of stratification that we were seeing in the lake during our sampling. Also the turnover of the lake could be accelerated during the rainy season. Since we were sampling just after the rainy period, there may not have been enough time for stratification to develop. In any case, to assess the health of the lake, a more periodic sampling would need to be implemented that incorporates seasonal (rainy vs. dry) and event-driven (Hurricane Mitch) changes.

Soil Analysis and Observations

Borings were taken at various points throughout the deltaic splay area at the mouth of the Polochic River. The intact sediments were then visually analyzed for soil type, color, and layering for indication of abnormal sedimentation as a result of Hurricane Mitch.

Core 1 (fig. 4) was taken on an exposed subaerial splay located at the mouth of the Polochic River. We observed no apparent layering, and the core was homogeneous silty sand throughout. Core 2 (fig. 5) was taken at 30 cm water depth approximately 20 m from core 1. We observed organic lenses at depths of 43 and 56 cm. We also observed finer silty sand with a lighter color than the rest of the strata at 32-39 cm depth. A third core (no picture available) was taken at a water depth of 56 cm. The total core length was 60 cm, and at 0-14 cm silty sand with mica visible was prevalent. At 14-18 cm oxidation deposits were noted, and at 26-27 cm a layer of fine material was present. At 43 cm we noted a fine brown layer of approximately 0.5 cm thick. The 45-60 cm section of the core was the same as the rest.

Core 4 (fig. 6) was taken 20 m from the site of core 1 at a water depth of 24 cm. The 0-13 cm section consisted primarily of silty sand. However, we observed 1 cm thick peat layers at numerous depths, including those at 13, 33, 35, 42 and 47 cm. At 42-45 cm depth, a darker reduced layer appeared. Core 5 (fig. 7) was similar to core 4 in that it was taken 20 cm from the site of core 1 at a water depth of 24 cm. Again, we observed 1-cm thick peat layers at 24, 27, 30, 34, 43, and 49 cm depth.

Core 6 (fig. 8) was taken upstream from the mouth of the Polochic River at a point 1 km from Site 1. The sample was taken 20 m inland from the shoreline at a site flooded only during extreme high water events. No obvious hurricane impact signature was observed; the top 10 cm layer was oxidized sandy clay, and the 10 cm layer below that was reduced gray clay.

Core 7 (fig. 9) was taken east of the Polochic River where water column profiles were taken on the previous day (15° 29' 14.7" N, 89° 21' 49.4"W). The depth of the water was approximately 52 cm, and the top 0-18 cm consisted of silty ooze. We observed sandy silt for 18-53 cm depth. An eighth core (no picture available) was taken 10 m nearshore from site 6 at a water depth of 61 cm. The 0-7 cm section consisted of silty ooze, and the 7-20 cm section was sandy silt.

Conclusions

Overall, we found no apparent evidence of Hurricane Mitch impact in the sediment cores or water quality. We found dissolved oxygen levels to be surprisingly good, and stratification in the water column was only shown at the offshore site. Sediment cores revealed multiple depositional layers but nothing that could be obviously attributed to Hurricane Mitch. We were coring to a maximum depth of 60 cm, which may have been too shallow to observe the sedimentation event that occurred 2 years earlier as a result of the massive flooding reported during the storm. We observed peat layers at the mouth of the river, which probably delineated relatively normal weather events that had occurred over the past rainy season. It seems that sedimentation and accretion processes in the delta are rapid. Therefore, it is possible that our analysis was too late to detect the sedimentation event that occurred as result of Hurricane Mitch.

Acknowledgments

Jorge Cordona, Director, and the staff of the Refugio de Vida Silvestre Bocas del Polochic (Defensora Naturalenza) provided boat access to field research sites as well as logistical support. Scott Kemmerer, Rebecca Moss and Tricia Lavin, Johnson Controls, Inc., assisted with data management and report preparation and organization. Wylie Barrow and Ed Proffitt, USGS, provided useful comments to earlier drafts of the manuscript. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Appendix: Species Lists

Wetland Vegetation

We observed the following species of plants during our investigation:
Emergent: *Typha* sp., *Phragmites* sp., *Hydrocotyl* sp., *Paspalum repens, Cyperus* sp.
Floating: *Eichhornia crassipes, Salvinia minima, Nymphaea ampla, Pistia stratoides, Azolla* sp.
Submersed: *Ceratophyllum sp., Hydrilla verticillata, Vallisneria americana, Potamogeton* sp., *Utricularia* sp.

Birds

Defensora Naturaleza reports 251 species recorded in the area, 80 of which are migratory. We observed American coot (*Fulica americana*), anhinga (*Anhinga anhinga)*, bat falcon (*Falco rufigularis*), black-bellied whistling duck (*Dendrocygna autumnalis*), black vulture (*Coragyps atratus*), black-necked stilt (*Himantopus mexicanus*), black-headed siskin (*Carduelis notata*), brown pelican (*Pelecanus occidentalis*), chestnut-sided warbler (*Dendroica pensylvanica*), cormorant (*Phalacrocorax brasilianus*), great egret (*Casmerodius albus*), green heron (*Butorides striatus*), great-tailed grackle (*Quiscalus mexicanus*), jacana (*Jacana spinosa*), limpkin (*Aramus guarauna*), magnificent frigatebird (*Fregata magnificens*), muscovy duck (*Cairina moschata*), northern oriole (*Icterus galbula*), osprey (*Pandion haliaetus*), purple gallinule (*Porphyrio martinicus*), red-lored parrot (*Amazona autumnalis*), ringed kingfisher (*Megaceryle torquata*), roadside hawk (*Buteo magnirostris*), royal tern (*Sterna maxima*), scaled pigeon (*Columba speciosa*), snail kite (*Rostrhamus sociabilis*), sun bittern (*Eurypyga helias*), tricolored heron (*Egretta tricolor*).

Mammals

Howler monkey (*Alouatta pigra*)

Table 1. Location and water quality data taken from sites 1, 2 and 3 near the Polochic River.

	Site 1	**Site 2**	**Site 3**
Location	NE outlet	S. Outlet	W. of mouth
Latitude	15° 28' 48.4" N	15° 29' 01.4" N	15° 29' 14.7" N
Longitude	89° 22' 25.9" W	89° 21' 41.9" W	89° 21' 49.4" W
Sample Date	17 Jan 2001	17 Jan 2001	17 Jan 2001
Sample Time	1400 CST	1430 CST	1700 CST
Conductivity	258FS	162.5FS	205.0FS
Dissolved Oxygen	96.9% (8.14mg/l)	93.6% (7.82mg/l)	9.51 mg/l
Temperature	23.5° C	23.5° C	27.6° C
Salinity	0 ppt	0 ppt	0 ppt

Table 2. Location and water column temperature and dissolved oxygen profiles at site 4, 300 m south of the mouth of the Polochic River.

Location: 15° 29' 8.1" N 89° 21' 37.3" W

Date and time: 17 January 2001, 1710 CST

Depth	Temp (°C)	% Dissolved oxygen (DO)
Surface	26.4	109.1
1 m	26.4	107.8
2	26.4	108.7
3	26.4	108.1
4	25.5	101.9
5	25.5	101.9
6	24.5	96.9
bottom (6.5 m)	24.6	84.0

Table 3. Location and water column temperature and dissolved oxygen profiles at site 5, approximately 1 km south of the mouth of the Polochic River (January 17, 2001).

Location:	15° 30' 26.8" N	89° 20' 05.8" W
Depth	Temp (°C)	% Dissolved oxygen (DO)
Surface	26.2	108.0
1 m	26.2	107.4
2	26.0	107.7
3	25.6	107.6
4	25.6	106.6
5	25.5	106.7
6	25.4	105.9
7	25.3	104.9
8	25.3	105.3

Table 4. Location and water column temperature and dissolved oxygen profiles at site 6, near the middle of Lake Izabal (January 18, 2001).

Location:	15° 26' 46" N	89° 15' 96"W
Depth	Temp (°C)	% Dissolved oxygen (DO)
Surface	28.4	97.3
1 m	26.6	97.1
5 m	25.3	94.3
10 m	25.2	76.5
13 m (bottom)	24.1	64.9

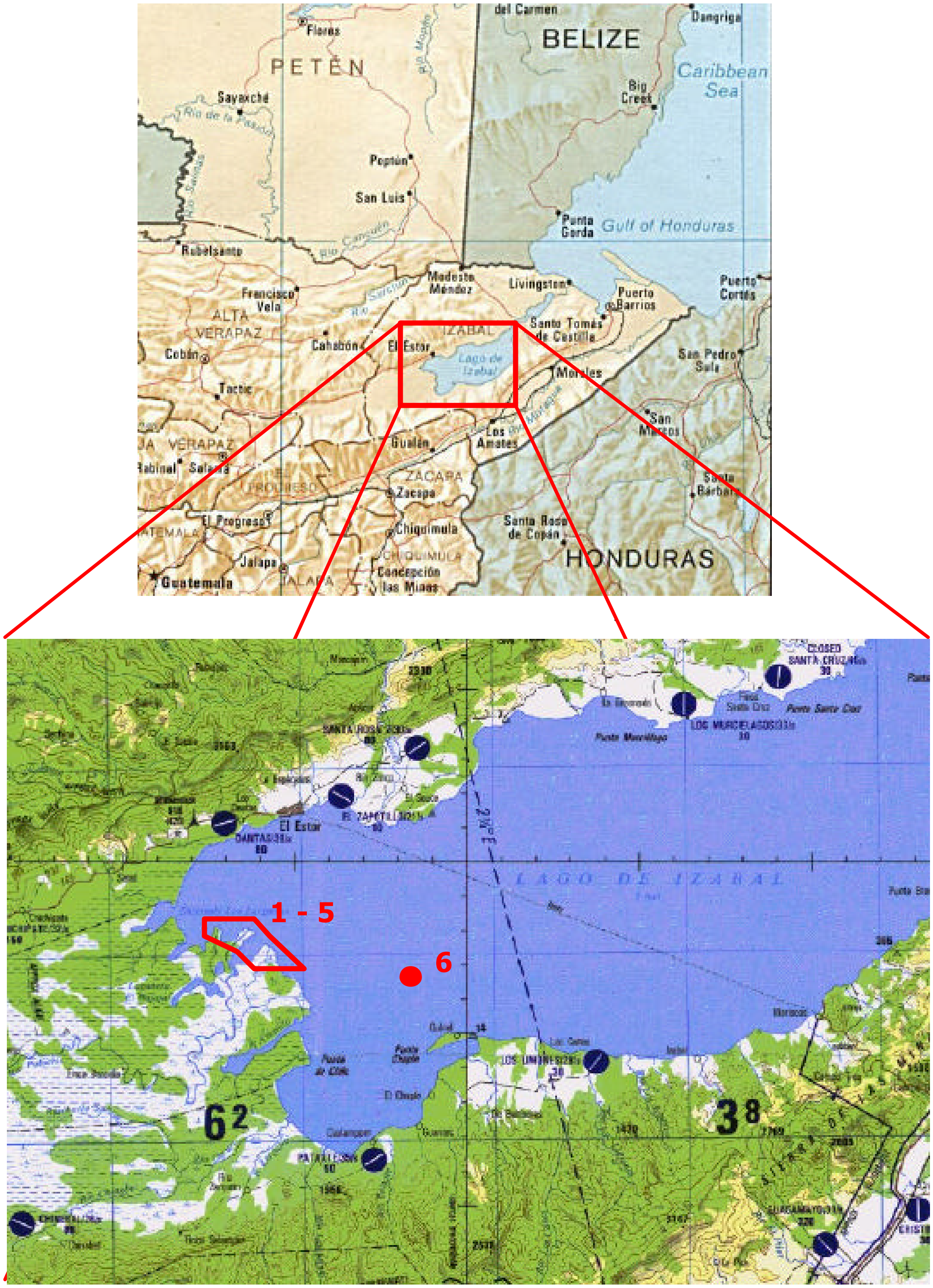

Figure 1. Eastern Guatemala and Lake Izabal. Map inset (bottom) shows sampling sites around the mouth of the Polochic River (sites 1-5) and central Lake Izabal (site 6).

Figure 2. Aerial view of northeast distributary of the Polochic River with visible sediment plume.

Figure 3. Aerial view of the mouth of the southern distributary of the Polochic River with very large sediment plume visible and numerous outwash splays.

Figure 4. Core 1 taken on exposed subaerial splay at the mouth of the Polochic River. There was no apparent layering, and there was homogeneous silty sand throughout.

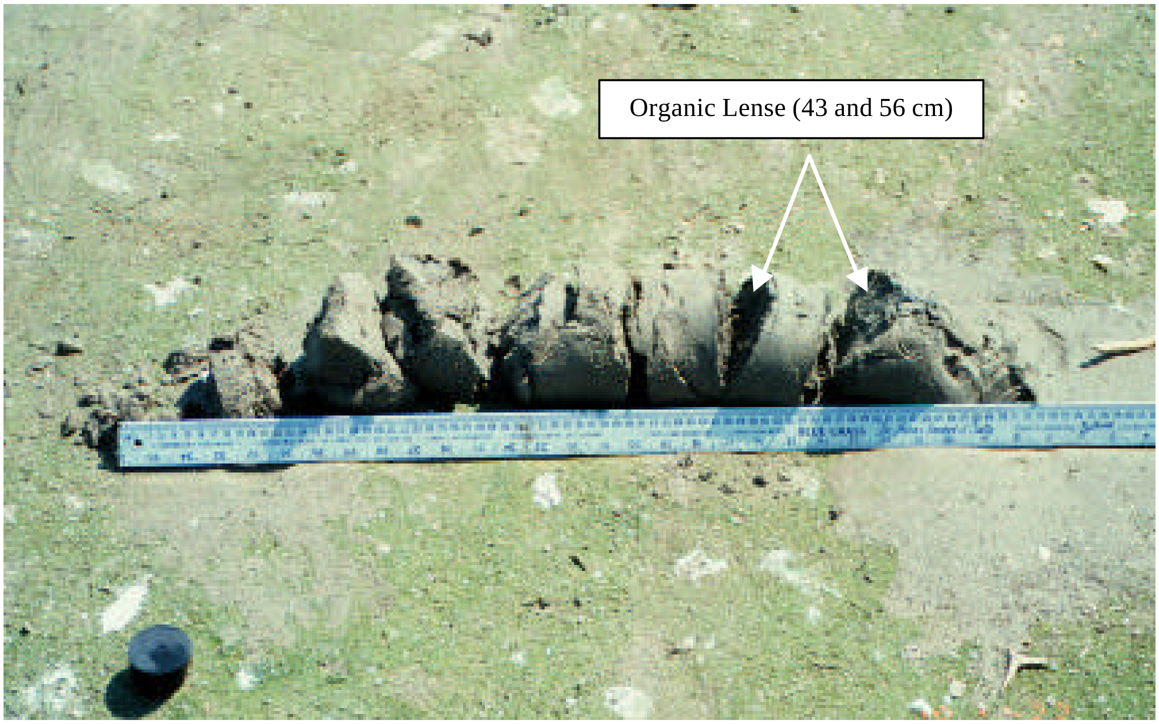

Figure 5. Core 2 was taken at 30 cm water depth approximately 20 m from core 1. We noted organic lenses at 43 and 56 cm. Depth of 32-39 cm was finer silty sand with a lighter color than the rest of the strata.

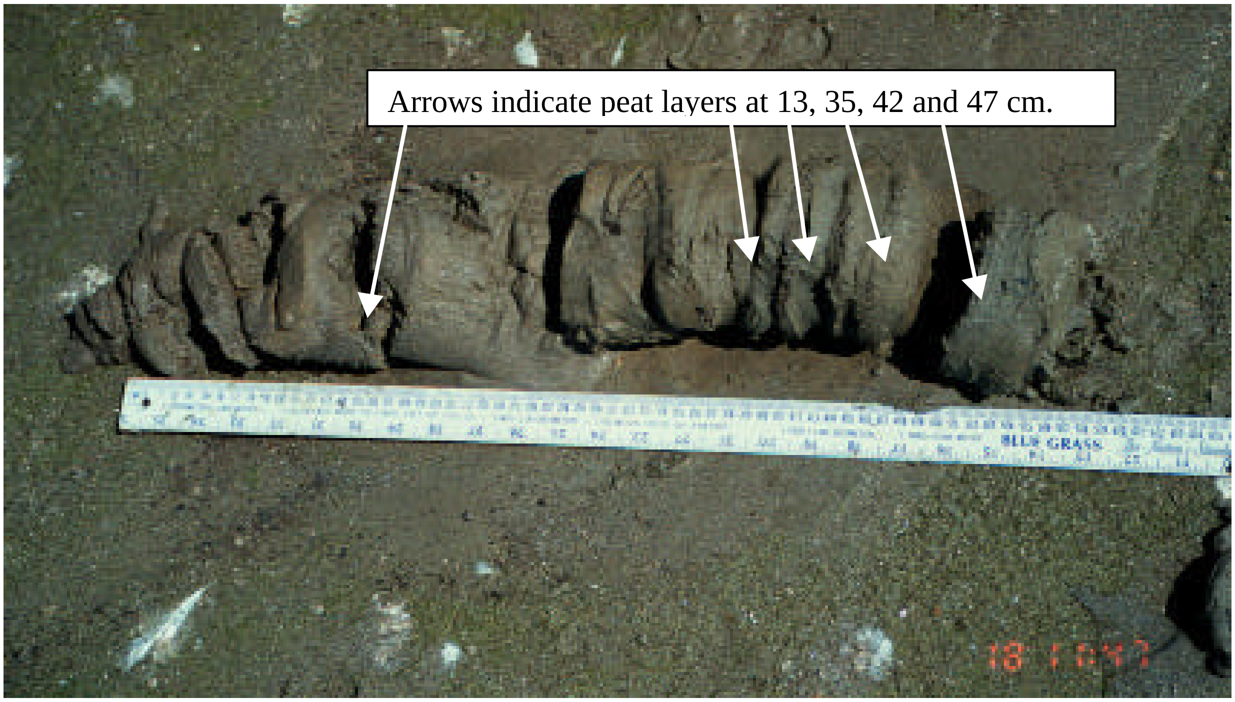

Figure 6. Core 4 taken 20 m from the site of core 1 at a water depth of 24 cm. The first 13 cm were silty sand, and we observed 1-cm thick peat layers at depths of 13, 33, 35, 42, and 47 cm. There was a darker, reduced layer at 42-45 cm.

Arrows indicate peat layers at 24, 27, 30, 34, 43 and 49 cm depths

Figure 7. Core 5 taken 20 cm from site of core 1 at water depth of 24 cm (similar to core 4). Peat layers 1-cm thick were observed at 24, 27, 30, 34, 43, 49 cm depths.

Figure 8. The core 6 site was located upstream from the mouth of Polochic River at a point 1 km from site 1. The sample was taken 20 m on shore at a site flooded only during extreme high water events. No obvious hurricane impact signature was observed. The top 10 cm layer was oxidized sandy clay and the 10 cm layer below that was reduced gray clay.

Figure 9. Core 7 site east of Polochic River where water column profile was recorded on the previous day (Location: 15° 29' 14.7" N, 89° 21' 49.4" W). Depth of water was 52 cm, and at 0-18 cm, sediment was silty ooze. At depths of 18-33 and 33-53 cm, layers were sandy silt.