NCKRI Report of Investigation 1

Geologic and Hydrologic Reconnaissance of Las Cruces, Petén Department, Guatemala

National Cave and Karst Research Institute

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January 2011

National Cave and Karst Research Institute

Published and distributed by

National Cave and Karst Research Institute

Dr. George Veni, Executive Director

400-1 Cascades Avenue
Carlsbad, NM 88220 USA

www.nckri.org

The citation information:
Land, Lewis, and George Veni. 2011. Geologic and Hydrologic Reconnaissance of Las Cruces, Petén Department, Guatemala: Report of Investigation 1. Carlsbad, NM: National Cave and Karst Research Institute.

Front cover photo: Flooded sinkhole near Las Cruces

ISBN-13 978-0-9795422-9-9

NCKRI Organization and Mission

NCKRI was created by the U.S. Congress in 1998 in partnership with the State of New Mexico and the City of Carlsbad. Initially an institute within the National Park Service, NCKRI is now a non-profit 501(c)(3) corporation that retains its federal, state, and city partnerships. Federal and state funding for NCKRI is administered by the New Mexico Institute of Mining and Technology (aka New Mexico Tech or NMT). Funds not produced by agreements through NMT are accepted directly by NCKRI.

NCKRI's enabling legislation, the National Cave and Karst Research Institute Act of 1998, 16 U.S.C. §4310, identifies NCKRI's mission as to:

1) further the science of speleology;
2) centralize and standardize speleological information;
3) foster interdisciplinary cooperation in cave and karst research programs;
4) promote public education;
5) promote national and international cooperation in protecting the environment for the benefit of cave and karst landforms; and
6) promote and develop environmentally sound and sustainable resource management practices.

NCKRI Report of Investigation Series

NCKRI uses this report series to publish the findings of its research projects. The reports are produced on a schedule whose frequency is determined by the timing of the investigations. This series is not limited to any topic or field of research, except that they involve caves and/or karst. To minimize environmental impact, few or no copies are printed. Digital copies of this and previous reports are available at no cost at www.nckri.org.

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Geologic and Hydrologic Reconnaissance of Las Cruces, Petén Department, Guatemala

Lewis Land and George Veni
National Cave and Karst Research Institute

Introduction

Las Cruces is one of the largest towns in the department of Petén in northern Guatemala (Figure 1). Heavy rainfall associated with a hurricane in 2008 and a tropical depression in 2010 caused severe flooding, resulting in displacement of 7,000 residents. An Engineers Without Borders (EWB) team began investigations of the area to evaluate the potential for constructing a drainage channel around the north and west side of town to mitigate future flood events. However, they recognized the possibility for intersecting caves along that route that might complicate or defeat their efforts and asked the National Cave and Karst Research Institute (NCKRI) to assist with this humanitarian effort by evaluating the potential for underlying caves. EWB (2010) provided the data specific to the Las Cruces area described below in this report.

Hydrogeologic Setting

Petén is bounded to the north and northwest by Mexico and to the east by Belize. The geology of northern Guatemala is relatively simple compared to the southern part of the country, which includes a transform boundary between the North American and Caribbean plates, with associated volcanism, metamorphism, and extensive structural deformation. By contrast, most of Petén is underlain by relatively undeformed shallow marine carbonate bedrock of Cretaceous and Tertiary age. Thick limestone deposits and the humid tropical climate are responsible for the extensive karst topography of northern Guatemala. The Petén region has limited surface drainage relative to the rest of the country, typical of karst terrain.

In the general vicinity of Las Cruces, a layer of unconsolidated non-carbonate sediment of variable thickness (zero to several meters) overlies limestone bedrock. In the immediate vicinity of the village, the elevation decreases from east to west, reflecting the distribution of bedrock. Extensive outcrops of limestone are exposed on the east side of town, particularly in the northeast quadrant. Within the populated area of Las Cruces, isolated exposures of limestone near the center of town reflect the irregular character of the sediment-bedrock interface. The subdued topography on the west side of Las Cruces coincides with very limited limestone outcrops.

There is abundant evidence for karstic conditions in the area. El Tragante, a small cave in the center of town, is formed in a limestone knoll with ~2 m of relief. The cave entrance is about 4 m in diameter, but the cave itself extends only about 8 m and narrows to a passage about 50 cm in diameter that is choked with trash (Figure 2). A smaller second entrance that does not receive significant natural drainage is present about 15 m west of the main entrance to the cave. Because of limited access, its connection to the main entrance is assumed but not known. In addition to El Tragante, a sinkhole approximately 25 m in diameter occurs on the north side of town (cover photo). Las Cruces residents also report the existence of a second cave within the village limits that was filled recently to prevent access by children and animals.

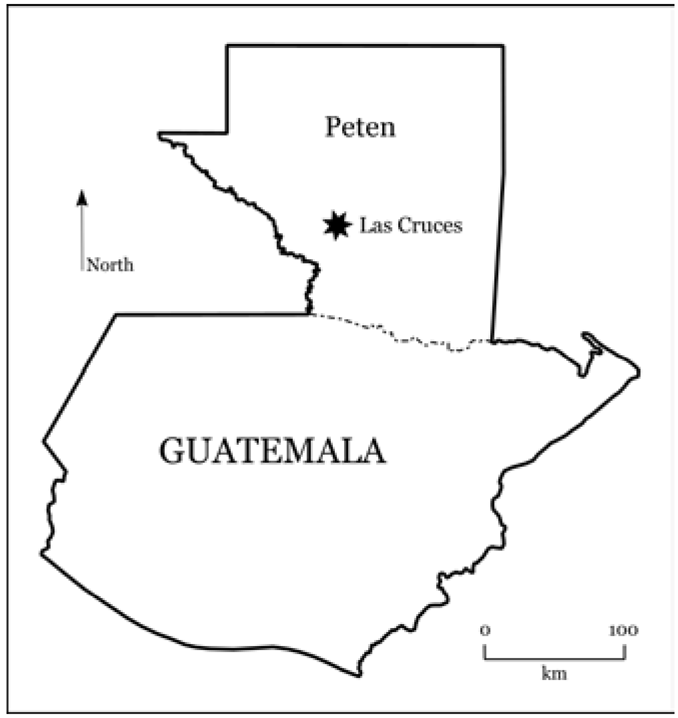


Figure 1. *Map of Guatemala with the location of Las Cruces*

Detailed hydrologic information for the village of Las Cruces and surrounding area is almost non-existent. At this stage of investigation, only a general conceptual model is possible based on observations of local outcrops, wells, and test pit results from this study.

The north half of Las Cruces has access to a municipal water supply, which pumps water from a 90-m deep well on the east side of town that is screened in limestone. In addition, many households either supplement their water

Photo Courtesy L. Land, NCKRI

Figure 2*. Dr. Lewis Land inspects the main entrance of El Tragante; a debris-catching grate had spanned the channel but was damaged by flooding and removed*.

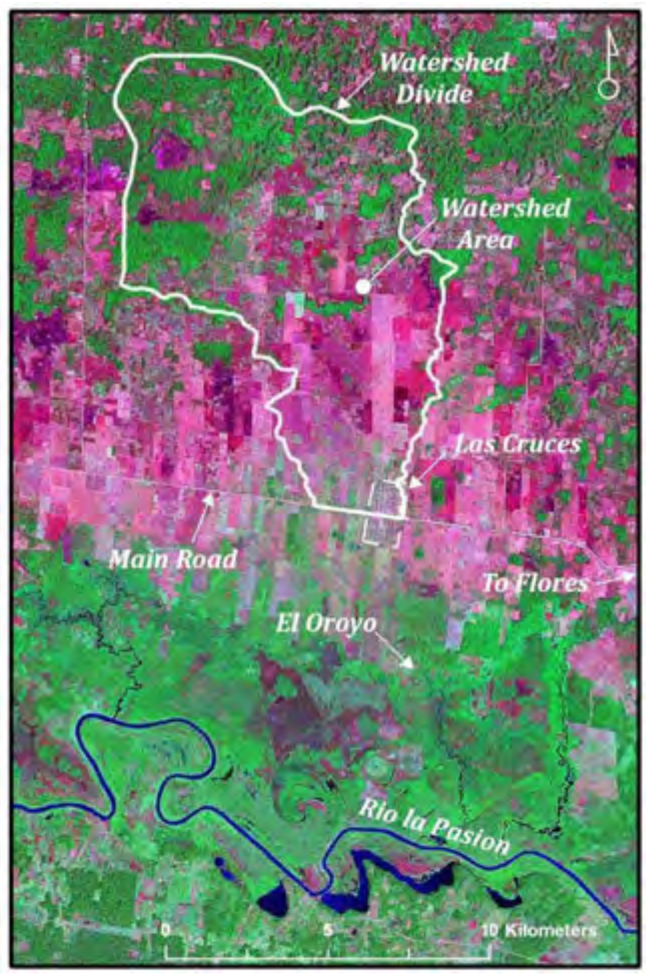
supply with, or rely exclusively on, shallow domestic wells. Several homeowners reported that their wells are sometimes dry for part of the year. Most of the domestic wells observed were hand-dug, which may account for their concentration on the west side of town where bedrock is overlain by a blanket of sediment. Several of the test pits dug for this study on the west side of town encountered limited water flow (<5 liters/min) at 3-4 m below ground level. These observations are consistent with a conceptual model of a deeper limestone aquifer overlain by several meters of clay and silt. The clay/silt overburden contains perched groundwater that provides water for small domestic wells. The municipal supply well draws water from the underlying limestone aquifer.

Karst Flooding and Groundwater Contamination

El Tragante is located at the south end of a drainage ditch running from north to south through the center of town. The community of Las Cruces exploits its natural karstic drainage system to manage floodwater and normal stormwater runoff. Surface floodwater is conveyed via the ditch into the cave and transported downgradient through karstic conduits; it is assumed to discharge from El Oroyo, a spring located roughly 4 km to the south.

Since about 1980, the 89-km^2 drainage basin flowing into Las Cruces has changed from a lowland jungle to deforested cattle ranches, corn fields, and papaya plantations (Figure 3). From 1990 to 2009, the area has experienced an average annual rainfall of 1,640 mm and until recently all drainage has flowed through El Tragante (EWB, 2010).

However, progressive deforestation has increased the flood pulse into the cave and in 2008 and 2010 the cave overflowed during a hurricane and tropical depression, flooding much of the northern part of Las Cruces with up to 3 m of water. Also, trash clogging the passage at the back of the cave inhibits its ability to efficiently transmit floodwater. Groundwater mounding also caused water to rise up to 0.6 m above the surface from wells to flood much of the southern part of the town. An estimated 7,000 residents were displaced and much property was damaged and



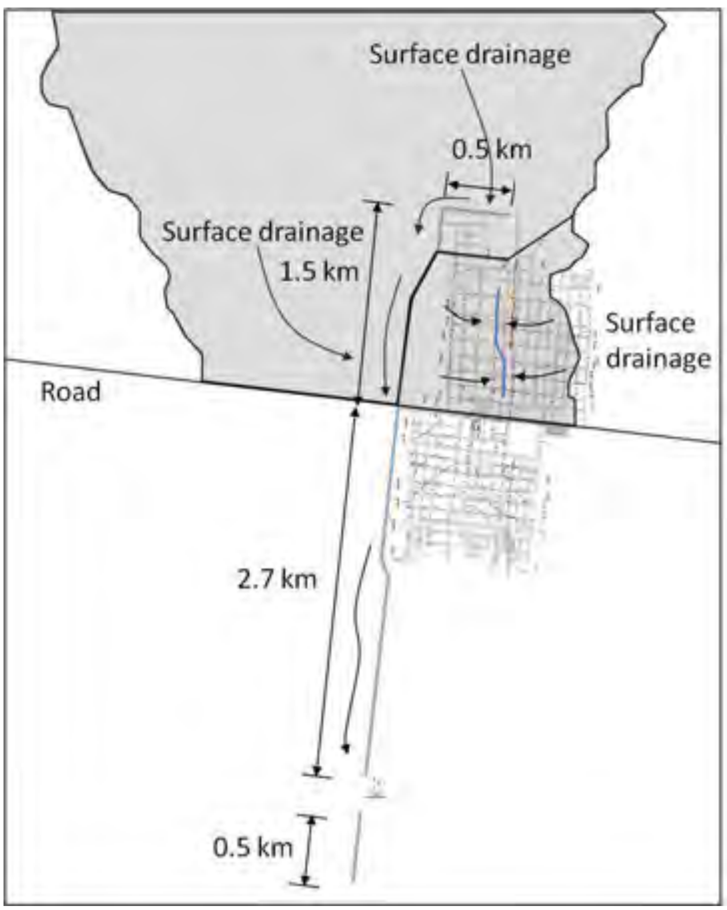
Map from EWB (2010)

Figure 3. *False-color infrared aerial photograph of the El Tragante drainage basin into Las Cruces.*

destroyed (EWB, 2010). Repeated flooding is expected unless the drainage area is reforested and/or some of the runoff is diverted away from Las Cruces. The drainage ditch also receives much of the graywater drainage as well as unknown quantities of domestic sewage and animal waste from homes located along the canal. In addition, a sewage line has been inserted directly into El Tragante's probable second entrance (Figure 4). Water samples collected from all wells in Las Cruces showed moderate to high levels of fecal coliform and *E. coli* bacteria, probably associated with the widespread use of pit latrines in the village as well as the discharge of graywater and sewage into the cave. Most residents rely on either bottled water or water from the municipal water distribution system. A sample collected from the municipal supply well had low levels of fecal coliform (EWB, 2010), in spite of the fact that raw sewage is being injected directly into the karstic aquifer beneath Las Cruces. The position of the municipal well upgradient from El Tragante may account for the relatively low level of contamination found in the well samples.

Photo courtesy L. Land, NCKRI

Figure 4. *Sewage pipe into the probable second entrance of El Tragante; this entrance is 3 m deep.*



Adapted from unpublished EWB figure

Figure 5. *Proposed route of diversion channel around Las Cruces; the short channel in the north-central part of town flows into El Tragante at its south end and the gray area to the north is the watershed for that channel .*

Flood Remediation Channel: Evaluation

Engineers from EWB proposed excavation of a 5.2-km long channel that would capture the majority of floodwaters entering the north side of Las Cruces, and divert them via the channel west and then south of town (Figure 5). The channel would be approximately 5 m wide by 3 m deep and prone to intersecting a cave during excavation. It could also collapse at a later time by water in the channel piping soil into underlying cavities, which could shift the location of flooding by surface overflows and continue flooding by groundwater mounding.

NCKRI geologists recommended conducting an electrical resistivity survey along the length of the proposed channel to identify any significant caves so EWB could reroute or design the channel accordingly. Logistical issues with transporting the resistivity equipment to Las Cruces prevented its use, so a second plan was developed to evaluate the stability of the channel route with the equipment that was available.

Using a backhoe, 25 tests pits were dug at 150-200 m intervals along the proposed channel's route to evaluate the near-surface geology and soil conditions. The pits had depths of 3.5 to 4 m (maximum depth was dictated by the length of the backhoe arm), and assessments were made of sediment cover, depth to bedrock, and locations of soil piping, caves, and other karst features in the subsurface (Figure 6). Information from a recently-excavated cesspit was also included as part of the geologic investigation. A Garmin 76S handheld GPS receiver was used to collect location and elevation data

Photo courtesy L. Land, NCKRI

Figure 6. *Backhoe excavating Test Pit 40.*

at each station, accurate to within a few meters. Pit depths were measured with a steel tape.

Twenty-two of the 25 pits encountered only soil and dense clay. These pits represent about 90% of the total length of the survey. Two of the pits (Test Pit 220 and Test Pit 240) exposed weathered limestone bedrock 1.5 to 3.5 m below ground level, and one unearthed several large limestone boulders at ~3.5 m, suggesting proximity to bedrock. In addition, four pits in the southern portion of the survey encountered limited water flow. We were unable to excavate test pits between Test Pit 90 and Test Pit 240 because of access limitations (individual homes were in the way); thus, no information about depth to bedrock is available for ~500 meters along that portion of the proposed channel. Appendix A provides complete descriptions and photographs of each test pit.

Conclusions

Results of the test pit survey, coupled with observations of the local geology, indicate the presence of an irregular bedrock surface overlain by one to several meters of clay and silt on the north and west sides of Las Cruces. Test pit and borehole data have inherent limitations when evaluating depth to bedrock in karst terrain. That said, it appears that limestone bedrock is probably greater than 4 meters deep over ~90% of the length of the proposed channel. Near-surface bedrock (<4 m) or limestone boulders indicating proximity to bedrock were encountered in three pits over a distance of roughly 500 m, along which more difficult excavation conditions are anticipated.

Although no caves or soil pipes were encountered in the test pits, caves are obviously present in the vicinity of Las Cruces. It is thus possible that leakage from the drainage channel into underlying caves or karst conduits may initiate sinkhole collapses. Ideally, the channel should be lined to prevent or minimize leakage, but budget constraints for the community may not permit this. For a more permanent solution, the people of Las Cruces are encouraged to reforest the town's drainage area with trees and other plants that will reduce runoff while yielding economically valuable harvests. Alternatively, or in combination, the example of the town's ancient Maya ancestors should be followed by terracing the landscape to reduce runoff and soil erosion, which is a well-recognized environmental and economic problem for the region.

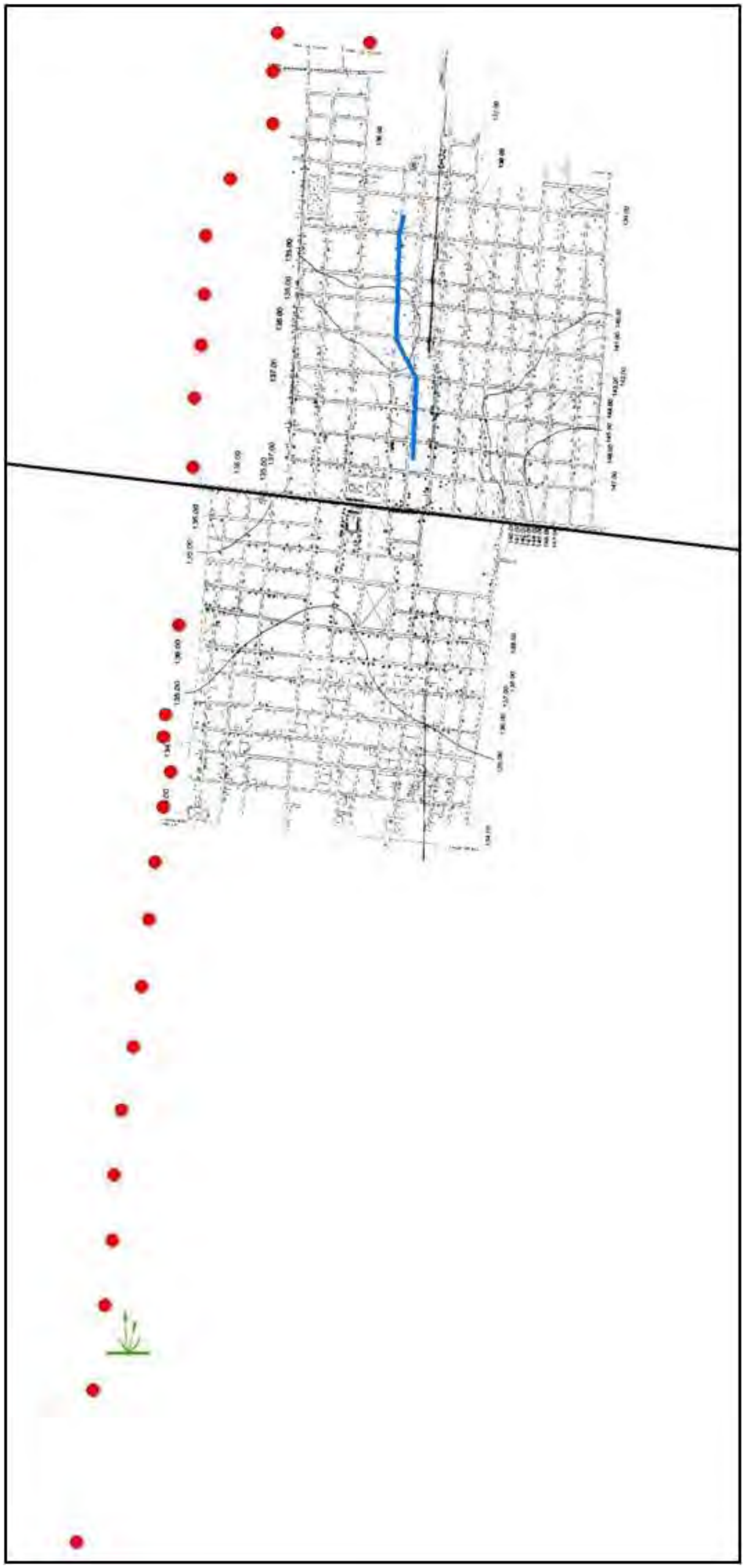
While remediation of groundwater quality was not a part of this study, contamination of the karstic groundwater supply would be at least partially mitigated by removal of the sewage line into the probable second entrance of El Tragante. In addition, Las Cruces residents should stop discharging graywater and sewage into the existing canal, since that waste is transported directly into the limestone aquifer via El Tragante. Lastly, the installation of a debris rack, designed to keep trash from entering the cave and not restricting recharge, would reduce both flooding and groundwater contamination.

References

Engineers Without Borders. 2010. Flood assessment and mitigation design project: preliminary design report. Engineers Without Borders, Chicago, Illinois.

Appendix A
Test Pit Descriptions

This appendix provides descriptions and photographs of the test pits, organized geographically along the proposed channel from northeast to south (Figure A1). Universal Transverse Mercator (UTM) coordinates are indicated as easting, northing, and elevation in units of meters. The test pits north of the highway that bisects the town were excavated on 25 January 2011 and the test pits south of the highway were excavated the following day.



Adapted from EWB figure

Figure A1. *Map of Las Cruces showing the test pits (red dots). The blue line is the drainage channel that flows into El Tragante; the black line that bisects the town is the local highway.*

Test Pit 250

Coordinates: 788750, 1845371
Elevation: 126 m
Photos: Figures A2 and A3

Description: Maximum depth 3.5 m. Reddish-brown soil (silt, clay, organics). Clay content increases slightly with depth. Slight water flow (<1 L/min) encountered near the base of the pit. This is the only test pit excavated on the east-west leg of the proposed channel on the north side of town. Therefore, investigators should use caution in extrapolating these results to the rest of the east-west transect.

Photo courtesy L. Land, NCKRI
Figure A2. *Backhoe excavation of Test Pit 250. Lewis Land in center of group on right.*

Photo courtesy of L. Land, NCKRI
Figure A3. *Backhoe excavation of Test Pit 250.*

Test Pit 10

Elevation: 129 m
Photos: Figures A4 and A5

Description: Maximum depth 3.7 m. Orange-red clay, becoming lighter with depth. Dense red clay with gray streaks below 3 m. Stiff, highly-compacted red clay is present at the base of the pit. No water flow was encountered. This is the northernmost pit on the north-south leg of the proposed channel.

Photo courtesy L. Land, NCKRI

Figure A5. *Backhoe excavating Test Pit 10.*

Photo courtesy L. Land, NCKRI

Figure A4. *Test Pit 10.*

Test Pit 20
Coordinates: 788429, 1845274
Elevation: 129 m
Photos: Figures A6 and A7

Description: Maximum depth 4 m. Dense, orange-red clay. No water flow was encountered.

Photo courtesy L. Land, NCKRI

Figure A7. *Test Pit 20.*

Photo courtesy L. Land, NCKRI

Figure A6. *Backhoe excavation of Test Pit 20.*

Test Pit 30

Coordinates: 788428, 1845102
Elevation: 129 m
Photos: Figures A8 and A9

Description: Maximum depth 3.8 m. Light red clay, not as clumped and compacted as at the more northerly sites. No water flow was encountered.

Photo courtesy L. Land, NCKRI
***Figure A8**. Backhoe excavation of Test Pit 30.*

Photo courtesy L. Land, NCKRI
***Figure A9.** Dr. Land inspecting soil content from Test Pit 30 excavation.*

Test Pit 40
Coordinates: 788288, 1844919
Elevation: 130 m
Photo: Figure A10

Description: At this pit the transect turns southwest to follow a shallow, pre-existing ditch that is approximately 1.5 m deep. The backhoe was located in the ditch, thus the maximum depth below average ground level was about 5.5 m while the depth of excavation was 4 m. Unconsolidated, reddish-brown soil was present to the bottom of the pit; the soil was comprised of silt, organics, and a small amount of clay. Abundant limestone cobbles and boulders in the berm adjacent to the pre-existing ditch suggested the presence of near-surface bedrock excavated during construction of the channel. However, field assistants from the local community reported the rock is part of an ancient Maya wall, probably for a terrace. The absence of any subsurface limestone confirms this hypothesis, which is further supported by the presence of small, poorly preserved limestone structures of obvious human origin within 100 m of Test Pit 40. One of these structures is a rubble-walled pit constructed without mortar, which a local guide suggested was used as storage for valuables by the Maya (Figure A11).

Photo courtesy L. Land, NCKRI
Figure A10. *Backhoe excavation of Test Pit 40.*

Photo courtesy L. Land, NCKRI
Figure A11. *Rock-lined pit near Test Pit 40 of presumed Maya origin.*

Test Pit 50
Coordinates: 788206, 1844732
Elevation: 135 m
Photo: Figure A12

Description: Maximum depth 3.9 m. Deep red clay-rich soil from the surface extends to the bottom. From this pit, the transect turns due south into open fields, following a property line.

Photo courtesy L. Land, NCKRI

***Figure A12**. Test Pit 50.*

Test Pit 60

Coordinates: 788201, 1844535
Elevation: 134 m
Photo: Figure A13

Description: Maximum depth 3.7 m. Clay-rich red soil, becoming more compacted with depth, with dense, orange clay at the bottom.

Photo courtesy L. Land, NCKRI

Figure A13. *Backhoe excavation of Test Pit 60.*

Test Pit 70
Coordinates: 788192, 1844367
Elevation: 132 m
Photo: Figure A14

Description: Maximum depth 3.8 m. Red-brown clay-rich soil with dense red clay at the bottom.

Photo courtesy L. Land, NCKRI

Figure A14. *Dr. Land inspecting soil content from Test Pit 70 excavation.*

Test Pit 80

Coordinates: 788170, 1844191
Elevation: 133 m
Photo: Figure A15

Description: Maximum depth 2.9 m. Red-brown clay-rich soil. Excavation was terminated before reaching the maximum depth possible for the backhoe because it broke an 8-cm diameter PVC pipe about 75 cm below ground level at the east end (nearer the village) of the pit. An estimated 1-2 L/min of water flowed from the broken pipe. Subsequent discussion with Rod Beadle of EWB suggested the pipe is a tile drain, placed to drain lower areas of fields where water could accumulate during rainy conditions.

Photo courtesy L. Land, NCKRI

Figure A15. *Broken PVC pipe in Test Pit 80.*

Test Pit 90

Coordinates: 788164, 1843961
Elevation: 135 m
Photo: Figure A16

Description: Maximum depth approximately 3 m. Red soil and clay. This station is a cesspit recently excavated by a homeowner 50 m north of the main east-west highway through Las Cruces. There was no evidence that the owner had begun using the cesspit, so it was incorporated into the test pit survey.

Photo courtesy L. Land, NCKRI

Figure A16. *Unused cesspit near Las Cruces, used as Test Pit 90 in survey.*

Test Pit 240

Coordinates: 788118, 1843438
Elevation: 126 m
Photo: Figures A17 and A18

Description: Maximum depth 3.6 m. Reddish-brown soil down to about 3 m. Dense orange clay was found at 3.5 m depth, at which point the backhoe encountered weathered limestone bedrock. Bedrock was encountered near the depth limit of the backhoe. The limestone was insufficiently exposed for a detailed examination, but it was clearly bedrock, not isolated limestone boulders. This pit is the northernmost site at which we found any material other than soil and clay. Test pit site spacing was increased to Test Pit 230 because of time constraints.

Photo courtesy L. Land, NCKRI

Figure A17. *Test Pit 240*

Photo courtesy L. Land, NCKRI

Figure A18. *Weathered limestone cobbles in sediment excavated from Test Pit 240.*

Test Pit 230

Coordinates: 788073, 1843139
Elevation: 125 m
Photo: Figure A19

Description: Maximum depth 3.7 m. Reddish-brown soil down to approximately 3 m followed by stiff orange-gray clay to the bottom.

Photo courtesy L. Land, NCKRI

Figure A19. *Sediment excavated from Test Pit 230.*

Test Pit 220

Coordinates: 788065, 1843065
Elevation: 127 m
Photo: Figures A20 and A21

Description: Maximum depth 3.3 m. Rich, dark-brown to black soil down to about 1.5 m, in contrast to surficial material in test pits to the north and south. Below that depth the backhoe encountered large limestone boulders and weathered bedrock. At this point the backhoe was relocated and the trench extended roughly 2 m north. Limestone cobbles and boulders 50-75 cm in diameter were encountered ~0.5 m below ground level. At a depth of 3.1 m water flowed into the pit at an estimated rate of 3 L/minute for about 10 minutes.

During a surface reconnaissance two days prior to excavating the pit, limestone cobbles and boulders were observed in a berm along a drainage ditch 10 m east of the pit (Figure A22). A shallow 10-m diameter by 1-m deep sinkhole was also found 30 m south of this pit, further suggesting the presence of near-surface bedrock in this area. Figure A23 shows a good example of the local limestone and its solution features. Local assistants from the community claimed the limestone boulders were Maya relicts, as at Test Pit 40. While some of the smaller rock unearthed by the backhoe may in fact be Maya building material, it seems clear that most of the limestone excavated at this site is bedrock

Photo courtesy L. Land, NCKRI
Figure A20. *Test Pit 220, showing water flowing into the bottom of the test pit.*

Photo courtesy L. Land, NCKRI
Figure A21. *Limestone boulders excavated from Test Pit 220.*

Photo courtesy L. Land, NCKRI
Figure A22. *Limestone cobbles and boulders in earthen berm near Test Pit 220.*

Photo courtesy L. Land, NCKRI
Figure A23. *Close-up of limestone boulder near Test Pit 220.*

Test Pit 100

Coordinates: 788090, 1842949
Elevation: 109 m*
Photo: Figures A24 and A25

Description: Maximum depth 3.7 m. Dark brown soil down to ~1 m followed by dense orange and gray clay with high plasticity to the near the bottom. The last few backhoe buckets brought up several limestone boulders, 30-50 cm in diameter, mixed with dense orange clay. Limestone boulders unearthed at this pit do not appear to be bedrock, although they may indicate proximity to bedrock. This is the southernmost station at which any material other than soil and clay were observed in the test pits.

* This recorded elevation is in error, about 15 m lower than the other elevations. It is probably the result of limited GPS satellite coverage when the elevation was calculated.

Photo courtesy L. Land, NCKRI
***Figure A24**. Test Pit 100.*

Photo courtesy L. Land, NCKRI
***Figure A25.** Weathered limestone boulder excavated from Test Pit 100.*

Test Pit 110

Coordinates: 788066, 1842833
Elevation: 124 m
Photo: Figures A26 and A27

Description: Maximum depth 4 m. Brown soil down to about 1 m, underlain by dense orange clay that continues to the bottom. A trickle of water (<1 L/min) flowed into the base of pit.

Photo courtesy L. Land, NCKRI

Figure A26. Test Pit 110.

Photo courtesy L. Land, NCKRI

Figure A27. Dense clay excavated from Test Pit 110.

Test Pit 120
Coordinates: 788038, 1842649
Elevation: 128 m
Photo: Figures A28 and A29

Description: Maximum depth 3.7 m. Red-brown soil, more friable than previous two test pits, followed by dense orange clay from 2 m to the bottom.

Photo courtesy L. Land. NCKRI
Figure A28. *Test Pit 120.*

Photo courtesy L. Land, NCKRI
Figure A29. *Sediment excavated from Test Pit 120.*

Test Pit 130

Coordinates: 788018, 1842459
Elevation: 125 m
Photo: Figure A30

Description: Maximum depth 3.5 m. Friable orange soil down to approximately 2 m followed by dense orange clay to the bottom.

Photo courtesy L. Land, NCKRI

Figure A30. *Sediment excavated from Test Pit 130.*

Test Pit 140
Coordinates: 787994, 1842238
Elevation: 126 m
Photo: Figure A31

Description: Maximum depth 3.6 m. Light reddish-brown, friable soil near the surface followed by dense orange clay to the bottom.

Photo courtesy L. Land, NCKRI

Figure A31. *Sediment excavated from Test Pit 140.*

Test Pit 150

Coordinates: 787967, 1842036
Elevation: 125 m
Photo: Figures A32 and A33

Description: Maximum depth 3.8 m. Brown soil near the surface underlain by dense orange and gray clay to the bottom.

Photo courtesy L. Land, NCKRI

Figure A32. *Test Pit 150.*

Photo courtesy L. Land, NCKRI

Figure A33. *Dense clay excavated from Test Pit 150.*

Test Pit 160

Coordinates: 787928, 1841826
Elevation: 126 m
Photo: Figure A34

Description: Maximum depth 3.6 m. Very dense, high plasticity orange and gray clay.

Photo courtesy L. Land, NCKRI

Figure A34. *Sediment and dense clay excavated from Test Pit 160.*

Test Pit 170

Coordinates: 787901, 1841610
Elevation: 129 m
Photo: Figure A35

Description: Maximum depth 3.6 m. Reddish-brown soil down to 2.5 m, underlain by dense orange clay. Water flowed into the pit at a depth of 3.1 m at an estimated rate of 4 L/min.

Photo courtesy L. Land, NCKRI

Figure A35. *Water flow into Test Pit 170.*

Test Pit 180

Coordinates: 787901, 1841610
Elevation: 129 m
Photo: Figure A35

Description: Maximum depth 3.6 m. Reddish-brown soil down to 2.5 m, underlain by dense orange clay. Water flowed into the pit at a depth of 3.1 m at an estimated rate of 4 L/min.

Photo courtesy L. Land, NCKRI

Figure A36. *Test Pit 180.*

Photo courtesy L. Land, NCKRI

Figure A37. *Sediment excavated from Test Pit 180.*

Test Pit 190

Coordinates: 787872, 1841179
Elevation: 124 m
Photo: Figure A38

Description: Maximum depth 3.8 m. Light-brown soil down to 1.5 m, underlain by dense orange and gray clay.

Photo courtesy L. Land, NCKRI

Figure A38. *Sediment excavated from Test Pit 190.*

Test Pit 200

Coordinates: 787832, 1840895
Elevation: 123 m
Photo: Figures A39 and A40

Description: Maximum depth 3.85 m. Brownish soil down to ~1 m, underlain by dense red and gray clay. Water flowed near the base of the pit at an estimated rate of 4 L/min.

Photo courtesy L. Land, NCKRI
Figure A39. *Test Pit 200.*

Photo courtesy L. Land, NCKRI
Figure A40. *Sediment excavated from Test Pit 200.*

Test Pit 210

Coordinates: 787779, 1840392
Elevation: 124 m
Photo: Figure A41

Description: Maximum depth 3.7 m. Reddish-brown soil, becoming more clay-rich with depth. The bottom of the pit was in orange clay.

Photo courtesy L. Land, NCKRI

Figure A41. *Sediment excavated from Test Pit 210.*

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