Weiss-Krejci, Estella and Thomas Sabbas
2002 'The potential role of small depressions as water storage features in the Central Maya Lowlands'. *Latin American Antiquity* 13:343-357.
THE POTENTIAL ROLE OF SMALL DEPRESSIONS AS WATER STORAGE FEATURES IN THE CENTRAL MAYA LOWLANDS

Estella Weiss-Krejci and Thomas Sabbas

Small depressions are a frequent landscape feature in the northeast Petén and northwestern Belize. Although generally considered the remains of seasonal ancient Maya water cisterns, they have not been subject to systematic study. Excavation of 16 depressions in northwestern Belize showed that these features are either natural sinkholes (dolinas) or quarried cavities. In three depressions, quarrying for construction materials and mining for clay was evident and two depressions are the remains of collapsed chultuns. Depressions probably also served as areas where household activities were carried out, they may have played a role as gardens, and were used as trash dumps. For one quarter of the sample, a water storage function was established. Water input-output calculations showed that these features could have held water year round and thus theoretically could have played a much more important role in supplying water than commonly assumed. The study indicates that Classic Maya population could have relied on decentralized water sources and suggests that hypotheses of centralized water management in the central Maya lowlands should be critically reviewed.

En el noreste del Petén y noroeste de Belice, el paisaje se caracteriza por la abundancia de pequeñas depresiones. Aunque generalmente se consideran restos de antiguos estanques de agua estacionales, todavía no han sido estudiadas de modo sistemático. Excavaciones en 16 depresiones pequeñas llevadas a cabo en el noreste de Belice mostraron que estas estructuras son tanto de origen natural del karst (dolinas) como cavidades excavadas. Cinco depresiones con fondo de roca madre dura y bajas densidades cerámicas y líticas son interpretadas como naturales. Tres depresiones en las cuales se halló sascab muy fino, barro y cortes en la roca madre probablemente formaron sascaberas, minas y canteras. Las dos depresiones más pequeñas resultaron ser chultunes derrumbados. Para un cuarto de la muestra se consideró que la función era el almacenamiento de agua. Esta evaluación se basa en la presencia de área de recogida de tamaño apreciable, sistemas de encauce y un substrato gris, muy duro, sobre la roca madre. Dicho substrato se interpreta como los restos destruidos de un antiguo sello. Algunas depresiones fueron usadas para diferentes actividades secuenciales no relacionadas. Una depresión probablemente sirvió como área de producción doméstica, otra pudiera haber sido usada para cultivo. Dos depresiones probablemente fueron empleadas como basureros. Algunos investigadores han cuestionado la capacidad de depresiones pequeñas para funcionar como fuentes abastecedoras permanentes. Se realizaron cálculos teóricos de uso y evaporación de agua, usando una depresión que se consideró como antiguo estanque de agua. Esta depresión almacena una capacidad aproximada de 57,000 litros de agua. Los cálculos muestran que depresiones pequeñas podrían mantener agua durante todo el año y, por tanto, que su papel en el suministro de agua durante los meses de sequía puede ser más importante de lo que generalmente se considera. El estudio indica que la población Maya Clásica podría haber dependido de fuentes de agua decentralizadas y que la hipótesis de control central del agua debe ser reconsiderada.

Most of the ancient Maya settlements in the northeastern Petén and along the northern Belizean/Petén border are located far from permanent water sources. Due to the region’s limestone karst geology, springs and rivers are seasonal and, despite high annual precipitation, water may become scarce during the 4-month dry season. The only natural and occasionally permanent water sources are watertight sinks, termed aguadas. They are most abundant along edges of bajos (Siemens 1979:380) and, in some instances, have been considerably modified by the ancient Maya (Carr and Hazard 1961; Domínguez Carrasco and Folan 1996).

Studies of the past decade have emphasized the necessity of rainwater collection and storage as an important aspect in the rise of Maya civilization.
(Adams 1991; Dunning et al. 1999; Scarborough 1993). During the rainy season a series of artificial and natural water sources may have been available to the ancient Maya, such as large constructed reservoirs, aguadas, small depressions and possibly some chultuns. However, some models hold that the need for dry-season water supply was only satisfied by large modified aguadas on bajo rims and large reservoirs close to ceremonial precincts (Scarborough and Gallopin 1991:661; Scarborough et al. 1994:103, 1995:109). Such great dependency on spatially centralized water control suggests to some scholars the existence of a strong centralized sociopolitical system (Dunning et al. 1999; Scarborough 1998) and a seasonally patterned social and economic structure (Lucero 1999).1

Small depressions2 so far have been neglected as a subject of systematic study, despite their frequent occurrence and dispersed distribution in the northeast Petén and northwestern Belize. Determining whether or not small depressions once were water receptacles that held water year-round provides critical knowledge in understanding the socioeconomic structure of lowland Maya civilization.

**Background**

Researchers of the University of Pennsylvania Tikal Project first suggested a possible water-storage function for small depressions3 and interpreted depressions associated with mound groups as household cisterns (pozas), as opposed to possible water holding quarried pits with no housemound association (Carr and Hazard 1961:14). The Tikal map shows 59 small depressions, but Puleston included 6 more that had been previously mapped as chultuns (Puleston 1983:45), which brings the number up to 65. Most of these features are found in terrain higher than bajos and are currently dry.

In a reevaluation of the Tikal map (without the changes suggested by Puleston), Scarborough and Gallopin (1991:661) assigned a rainy season water storage function to all 59 small depressions (47 pozas and 12 quarries) within the central 9 km² of Tikal. However, they assumed that in comparison to large reservoirs, small depressions were subject to dry season desiccation (Scarborough and Gallopin 1991:661).

While several excavations were conducted in the large reservoirs of Tikal between 1956 and 1968 (Coe and Haviland 1982:68–93), none of the smaller depressions were investigated. This lack of interest in small depressions remains as most water management related research in the central Maya lowlands focuses on large reservoirs (e.g., Scarborough et al. 1995), while small depressions are most often investigated only as a by-product of site excavation. This problem of scant attention to small household-level rainwater storage facilities is not restricted to the Maya area, but is also apparent in other areas, such as the Middle East, where water is a scarce resource (Wåhlin 1997).

Apart from an identification as cisterns (Hughbanks 1994:3; Lewis 1995:326), small depressions in the Maya lowlands have also been interpreted as natural sinkholes (Hughbanks 1995:75; Lene 1997), rock quarries, sascaberas, and clay mines (Folan 1982; Tourtellot and Rose 1993), and areas of agri-, horti-, and apiculture (Folan 1983:25; Gomez-Pompa et al. 1990; Kepecs and Boucher 1996).

**Investigation of Small Depressions in Northwestern Belize**

The research reported here examined the nature of small depressions within the Programme for Belize conservation and management area under the Programme for Belize Archaeological Project/PBAP (Adams 1994, 1995; Valdez 1995) and the La Milpa Archaeological Project/LaMAP (Hammond and Tourtellot 1993; Hammond et al. 1996; Tourtellot et al. 1993, 1994). This investigation was independent from the water resource and management studies directed by Dunning and Scarborough (Dunning et al. 1999; Scarborough et al. 1995).

Test excavation was conducted in 16 depressions located in seven different areas (see Figure 1 and Table 1): the Dos Bararas group (Figure 2a), 200-m Ridge Site Survey Block 1 (Figures 2b and 2c), the ceremonial precinct La Milpa East (Figure 2d), a residential area on the East Transect of the LaMAP 500 m from La Milpa East (Figure 2e), the ceremonial precinct La Milpa West, the center of the large site Wari Camp, and Wari Camp Survey Block 1 (Figure 2f). The areas around Wari Camp and the 200-m Ridge Site have been mapped by Laura Levi in cooperation with the first author. Maps within the realm of the La Milpa Archaeological Project were provided by Gair Tourtellot. Dos Bararas has been investigated by Brandon Lewis (1995).

Depressions were chosen for excavation from maps in order to achieve a cross sample of varying
sizes, shapes, contexts, and locations (see Table 1). Regardless of dimensions reported on maps, all excavated depressions were remeasured with tape and compass (Weiss-Krejci 1997, 1998, 2000). The excavated depressions are found on hilltops and slopes, eight depressions are located within 40 m of monumental architecture, seven depressions are located in residential areas and have small structures associated within 30 m, and one depression is not associated with any structure. Prior to excavation, the 16 depressions ranged in depth from 40 to 100 cm and in surface area from 18 to 722 m². Their shape was classified as either round, quadrangular, irregular, or as doublet. Doublets are depressions on steep slopes that enclose a round and deeper depression on the downhill side (e.g., Figure 2a: Depression No. 2; Figure 2b: Depression No. 7; Figure 2c: Depression No. 15). All three investigated doublets are associated with isolated house mounds.

Excavation followed natural levels and the main results are given in Table 2. Ceramics were counted and analyzed by Kerry Sagebiel for the LaMAP and Lauren Sullivan for the PbBAP; all other artifacts were processed by respective lab personnel.
Table 1. Data Summary for Investigated Depressions. All Measurements Refer to the State before Excavation.

<table>
<thead>
<tr>
<th>No.</th>
<th>Site and Original Depression Number</th>
<th>Operation (Suboperation Number)</th>
<th>Surface Depth (cm)</th>
<th>Surface Area (m²)</th>
<th>Shape</th>
<th>Location</th>
<th>Distance to Structure (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dos Barbaras (RB-4)</td>
<td>4 (A-D, F-I)</td>
<td>50</td>
<td>28</td>
<td>round</td>
<td>slope</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>4 (E)</td>
<td>90</td>
<td>126 (67)</td>
<td>doublet</td>
<td>slope</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Wari Camp (RB-56)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>slope</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>Survey Block 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>200 m Ridge Site (RB-60)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Survey Block 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>La Milpa East</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>East Transsect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assessment of Depressions

Depressions may be either of natural or artificial origin. Natural sinkholes (dolines) are a common phenomenon in karst systems (Jennings 1985:106; Lene 1997) and often occur in large numbers close together (Jennings 1985:114). Very small depressions also bear a hypothetical chance of resulting from ancient treefalls. Artificial depressions may have been quarried from surface caprock or represent the enlargement of natural depressions.

In order to determine origin and function of depressions we combined variables from surface observation, excavation, and artifact and soil analysis (see Tables 1 and 2).

The main variables to distinguish natural from artificial depressions were bedrock appearance and hardness, soil depth, and artifact density. Shallow depressions that displayed unquarried hard bedrock at the bottom and low sherd and debitage densities we interpreted as natural. Nine depressions were probably quarried, but only for three depressions with very fine sascab (sascabera), clay (clay mine), and cut marks exposed on the rim (rock quarry) are we able to suggest the use as a quarry or mine. A collapsed bedrock layer on top of cultural material in the two smallest depressions indicates collapsed chultuns and four deep depressions resembled water reservoirs. The assessment as a water feature rests on a combination of observations such as the presence of catchments several times the surface area and sufficient depth for storing water and guidance systems. In all four cases a hard gray layer, on top of smooth bedrock that we interpreted as the remains of an ancient sealing layer, marked those depressions as different from the rest.

Four depressions were sequentially used for other purposes through time. High sherd and debitage den-
Figure 2. Types of depressions and operations: a) Dos Barharas; b) and c) 200 m Ridge Site, Survey Block 1; d) La Milpa East; e) East Transect of the LaMAP; f) Wari Camp Survey Block 1.

SITIES IN UPPER STRATA OF TWO DEPRESSIONS POINT TO A USE AS TRASH DUMPS. ONE DEPRESSION MAY HAVE BEEN USED FOR SOME GRINDING ACTIVITY, AND ANOTHER ONE AS A GARDEN (TABLE 2).

TWO DEPRESSIONS (NO. 5 AND NO. 14) WERE NOT DEPRESSIONS AT ALL, BUT ONLY LOOKED LIKE DEPRESSIONS BECAUSE OF THEIR RELATIONSHIP WITH ADJACENT STRUCTURES. WE WILL NOT DISCUSS THEM.

NATURAL SINKHOLES (NOS. 6, 8, 11, 12, AND 16)

DEPRESSIONS NO. 6, NO. 8 (FIGURE 2C), AND NO. 16 (FIGURE 2E) ARE LOCATED FARHER AWAY FROM STRUCTURES THAN THE REST (TABLE 1), AND ALL BORDER OTHER DEPRESSIONS, SOME PROBABLY ALSO OF NATURAL ORIGIN. DEPRES-
Table 2. Data Summary and Evaluation of Excavated Depressions.

<table>
<thead>
<tr>
<th>Dep. of</th>
<th>Soil Depth</th>
<th>Total Depth</th>
<th>Origin</th>
<th>Observations and Materials</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Bedrock</td>
<td>(cm)</td>
<td>(cm)</td>
<td>artificial</td>
<td>a) collapsed bedrock</td>
<td>a) chultun</td>
</tr>
<tr>
<td>1 medium-hard</td>
<td>167</td>
<td>217</td>
<td></td>
<td>b) jar sherd layer with mano, several lithic and groundstone tools</td>
<td>b) grinding activity</td>
</tr>
<tr>
<td>2 powdery sascab</td>
<td>54</td>
<td>144</td>
<td>artificial</td>
<td>very fine sascab</td>
<td>sascabera</td>
</tr>
<tr>
<td>3 medium-hard</td>
<td>87</td>
<td>187</td>
<td>artificial</td>
<td>gray layer; steps</td>
<td>reservoir (228 m³)</td>
</tr>
<tr>
<td>4 medium-hard</td>
<td>74</td>
<td>134</td>
<td>artificial</td>
<td>a) gray layer; water inlet</td>
<td>a) reservoir (57 m³)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>b) hundreds of sherds, high lithic debitage density</td>
<td>b) trash dump</td>
</tr>
<tr>
<td>6 hard</td>
<td>64</td>
<td>114</td>
<td>natural</td>
<td>only two sherds; one lithic debitage</td>
<td>none</td>
</tr>
<tr>
<td>7 crumbly sascab</td>
<td>90</td>
<td>180</td>
<td>artificial</td>
<td>potter's clay; possible sherd tool</td>
<td>clay extraction</td>
</tr>
<tr>
<td>8 hard</td>
<td>53</td>
<td>103</td>
<td>natural</td>
<td>only two sherds</td>
<td>none</td>
</tr>
<tr>
<td>9 medium-hard</td>
<td>144</td>
<td>214</td>
<td>artificial</td>
<td>a) gray layer; ditch in catchment area</td>
<td>a) reservoir (151 m³)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>b) gravel layer with thousands of sherds and hundreds of lithics</td>
<td>b) cultivation</td>
</tr>
<tr>
<td>10 hard</td>
<td>50</td>
<td>130</td>
<td>artificial</td>
<td>a) cutmarks on margin of quarry wall</td>
<td>a) rock quarry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>b) hundreds of sherds; high lithic debitage</td>
<td>b) trash dump</td>
</tr>
<tr>
<td>11 medium-hard</td>
<td>46</td>
<td>126</td>
<td>natural?</td>
<td>few sherds and lithic debitage</td>
<td>none?</td>
</tr>
<tr>
<td>12 hard</td>
<td>33</td>
<td>123</td>
<td>natural</td>
<td>two sherds, few lithic debitage</td>
<td>none</td>
</tr>
<tr>
<td>13 medium-hard</td>
<td>92</td>
<td>152</td>
<td>artificial</td>
<td>collapsed bedrock; chultun lid in depression</td>
<td>chultun</td>
</tr>
<tr>
<td>15 medium-hard</td>
<td>83</td>
<td>183</td>
<td>artificial</td>
<td>gray layer</td>
<td>reservoir (37 m³)</td>
</tr>
<tr>
<td>16 hard</td>
<td>33</td>
<td>83</td>
<td>natural</td>
<td>one sherd, one lithic debitage, one mano</td>
<td>none?</td>
</tr>
</tbody>
</table>

sion No. 12 is situated in the plaza of La Milpa West and may well be of natural origin. The evaluation of Depression No. 11 at La Milpa East (see Figure 2d) as natural is more problematic since its proximity to Depression No. 10 and the slightly softer bedrock may indicate that it was also quarried.

Quarries and Mines (Nos. 2, 7, and 10)

Rock quarry. Depression No. 10 is the largest of all investigated. It is located right behind Structure 2041 at La Milpa East (Figure 2d) and probably provided stones for the construction of the site. The exposed rock face on the depression rim and cut marks on limestone blocks support that this depression started out as a rock quarry.

Sascabera. Depression No. 2 is a doublet depression (Figure 2a), which we identified as a pit mine. A 4-m long test trench that extended from the rim to the center revealed that the caprock had been cut away in ancient times in order to get to the underlying sascab, a material that was probably used for the production of lime. The sascab consists of a very fine almost powdery deposit ranging from white (2.5Y 8/2) to yellow (2.5Y 7/4) and orange (7.5YR 8/6) that had been mined to a depth of almost 1 m.

Clay mine. Excavation of a 3-m long test trench (Suboperation A) in the lower round area of Depres-

sion No. 7 (Figure 2b) revealed 20-to-50 cm diameter holes cut into crumbly sascab that held some clay. Further excavation into the sterile bedrock revealed natural clay inclusions. It seems that the entire depression served as a catchment for water that was directed into the lower part. During heavy rains the clay was washed out of the soil as a residue of the weathered bedrock and settled in the lower part of the depression, while the water evaporated or seeped into the bedrock. We observed similar processes of clay accumulation on the bottom of a depression situated in a recently dug quarry beside the road between Tres Leguas and Blue Creek. The clay of Depression No. 7 was examined by X-ray diffraction and showed a high quantity of clay minerals. Additional firing experiments by the authors confirmed the possible use as potter’s clay.

A mixture of Early and Late Classic ceramics was found in the clay holes of Depressions No. 7, among them a rather worn, spoon-shaped 11-cm long basal flange sherd, which might have served as a scoop to extract the clay. Depressions No. 10 and No. 2 only contained Late Classic ceramics.

Collapsed Chultuns (No. 1 and No. 13)

Two depressions that are very small started out as chultuns, underground chambers cut into the lime-

Depression No. 13, with a diameter of 4.5 m, is the smallest of all. It is located at La Milpa West in a little courtyard behind the main plaza. A rubble layer that probably once surrounded the *chultun* entrance was found inside the depression immediately above bedrock. *Chultuns* with circular entry shafts protected by rubble are common around La Milpa (Scarborough et al. 1995:109). Among the collapsed rubble, which contained Early and Late Classic ceramics, a semicircular stone was encountered that could have been part of the *chultun* lid. Above, a 60-cm thick stratum of collapsed bedrock was detected, indicating that the *chultun* roof had broken in. The upper part of the collapse debris contained many shells of the terrestrial gastropods *Neocyclotus dysoni*, a common find in the area (Covich 1983:134).

Depression No. 1 measures 6 m in diameter and is associated with an isolated house mound (Figure 2a). The construction date of the *chultun* that created this depression is probably in the Late Classic period, although a few Late Preclassic ceramics were encountered on the bottom together with fragments of *Pomacea* shells. On the depression rim, rubble and boulders that contained Tepeu 2/3 sherds and probably served as protection for the *chultun* entry shaft were found. Some of the larger boulders had fallen into the depression (Figure 3). The collapsed *chultun* roof consisted of a 50-cm thick limestone layer, the upper layers of which were filled with soil, Tepeu 2/3 sherds, lithic materials, and terrestrial snail shells.

**Household Activity Area (No. 1)**

After the collapse of the *chultun* roof in Depression No. 1, thick black soil (10YR 2/1) settled in the depression. This soil layer was interrupted by a stratum of small limestone pieces and hand-sized rocks, Tepeu 2/3 sherds, and several groundstone and chert tools (Figure 3). The limestone rocks derive from the surrounding depression rim and are of the same material as the groundstone tools. The entire layer is probably the result of quarrying the bedrock rim for limestone to make groundstone artifacts on the spot. Beneath an overhang, on the east side of the depression, large Late Classic jar sherds (from different jars) were laid out forming a support on which rested a *mano* (Figure 4). Something was ground there, but what it was is only a matter of speculation. What comes to mind is that depressions would be cool work areas, in this case providing morning shade. A drawing of a Mayapan house-group, for example, shows a *metate* resting in a depression (Bullard 1954:251, Figure 3).
Small Reservoirs (Nos. 3, 4, 9, and 15)

Four depressions show evidence of having served as small reservoirs. Depression No. 3 is the second largest in the sample (Figure 2f) and associated with a cluster of housemounds that lie approximately 250 m away from the Wari Camp ceremonial center at a 16-m lower elevation. A 5-m long test trench revealed irregular steps in the bedrock. Such ledges have been encountered in depressions excavated by Hughbanks (1994:3) and Lewis (1995:326) and are interpreted as steps into water cisterns.

Several test trenches were opened in and around Depression No. 4, a round depression downhill of the big plaza of Wari Camp (Figure 5). Excavations in the catchment showed that water would have run into this depression, and the depression rim revealed a water inlet.

Excavation in Depression No. 9, which is located at La Milpa East (Figure 2d), revealed a deep cut depression (Figure 6). West of the depression the first author encountered a 25-cm deep and 1.7-m wide ditch in the bedrock, which may have been part of a canal that guided water into the depression (Operation K14).

Depression No. 15 borders a second depression (No. 16) and is located in an area of major bedrock outcropping (Figure 2e). A test trench was excavated in the lower round part of this doublet depression. In contrast to the other three possible water receptacles, sherd and debitage densities were very low, implying that this depression was either occasionally used as a cistern or only saw a short span of use. The water receptacle was probably fed by the larger surrounding depression, which is about six times its size.

In all four depressions a peculiar gray hard layer between 10- and 30-cm thick overlay white mediumhard, smooth bedrock. In the field we interpreted the layer as the remains of a water-impermeable seal. Since the limestone bedrock is highly permeable, one or more modifications, in the form of an impermeable seal, would have been necessary to slow or inhibit leakage. That the Maya were aware of such simple modifications is evidenced by pavements of stone slabs discovered in the Palace Reservoir at Tikal (Harrison 1993:84), aguadas at Calakmul (Domínguez Carrasco and Folan 1996; Folan et al. 1995), and one Uaxactún reservoir (Smith 1950:61, Figure 99b). Chultuns in the northern lowlands are sometimes covered with a thick plaster layer that
may have prevented or slowed down leakage into the ground (McAnany 1990:266; Puleston 1971:324). Similarly, a layer of impermeable clay, as discovered in natural aguadas, may seal a water hole. But waterholes may be simply sealed with mud and organic matter, as it is done in modern cattle tanks in the unforested part of the Rio Bravo region.

In order to evaluate the sealing capacity of the gray layer, we entertained in situ water infiltration tests on layers in Depression No. 3 and No. 4, but these tests revealed extensive seepage. Mineralogical analysis from samples taken from No. 4 showed that the general composition of the layer is not significantly different from the underlying bedrock. However, these results may not necessarily disprove the ancient sealing capacities of the gray layer, which may have been entirely destroyed through decomposition, roots and other forms of bioturbation.

The four depressions ranged in capacity between approximately 37,000 and 228,000 liters. The gray layers in Depression No. 3, No. 4, and No. 15 contained Tepeu 2/3 sherds and indicate the use of the water reservoirs in the latter part of the Late Classic. The gray layer in Depression No. 9 contained Tzakol and Tepeu 1/2 sherds. The use of Depression No. 9 as a water reservoir must have ceased with the onset of the latter part of the late Classic.

**Cultivation (No. 9)**

After being used as a reservoir, Depression No. 9 was densely filled with gravel and thousands of sherds (Figure 6). The deposit dates to Tepeu 2/3 and was probably created around or after A.D. 750. The lower zone of the gravel stratum is 20-cm thick and consists of 2-to-10-cm diameter limestone pieces and large sherds. Above this there is a 10-cm-thick layer that consists of small sherds and small limestone pieces (1-to-2 cm in diameter). This stratum is overlain by three more layers: half a meter of light soil that contained sherds and limestone in lower quan-
tity, and two top postabandonment layers. The gravel and probably the overlying light-soil layer may represent the remains of an ancient horticultural feature.

The use of depressions for sheltered cultivation is known from the northern Lowlands (Folan 1983:25; Gómez-Pompa et al. 1990, 1987) and the southern Petén (Dunning et al. 1997; Kepecs and Boucher 1996). The thick gravel and sherd layer may have underlain the growing surface to allow extra drainage from the root zone during the rainy season. The thinner sherd and gravel stratum could have been used as mulch. Recent archaeological investigations around nearby Dos Hombres point to the use of gravel and sherd fills as mulch in house-lot gardens used to slow the loss of moisture during lengthy dry periods (Lohse and Findlay 2000).

Strewn among the gravel were several incensario fragments that probably pertain to one vessel. Censer fragments are primarily encountered in ritual contexts and have been connected with termination rituals at a variety of sites (Rice 1999:38). It may well be that the filling in and abandonment of the reservoir saw such ritual. On the other hand, the censer parts may be connected with the creation of the new garden or may have entered the depression coincidentally when the gravel and sherd layer was created. However, according to ceramicist Kerry Sagebiel the ritual component is strongly supported by the presence of several Daylight Orange, Darknight variety sherds.

Trash Dumps (No. 4 and No. 10)

High sherd and debitage densities in the upper layer of Depression 4 (a former reservoir) and in Depression No. 10 (originally a rock quarry) indicate that these depressions may have served as dumps after having lost their former functions. These deposits date to Tepeu 2/3.

Discussion

The study demonstrates that field survey alone is unable to reveal the true nature of a depression. Although we interpreted the two smallest depressions as collapsed chultuns, mapped size and depth cannot reveal real depth. Depressions No. 1 and No. 9 appeared rather shallow (Table 1, column 4) but turned out to be deep (Table 2, column 3); Depressions No. 2 and No. 12 appeared deep but soil depth was shallow.

Origin and varying functions could only be assessed through excavation. Not every depression is a cultural feature. Some artificial depressions were only used to provide limestone or clay, others have a two or multistage history such as Depression No. 9 that, after being quarried, probably served as a reservoir and later as a garden. Maybe depressions also served as trash dumps in their final stages like Depression No. 4 and Depression No. 10. While such use as garbage dumps may be expected, it does come as a surprise that depressions additionally played a
role in household activities such as the grinding that took place in Depression No. 1. Future investigations of housemounds and related research into household activities should include these features.

Small depressions of varying size and shape are a major feature of the landscape in the northeastern Petén and along the northern Belizean/Petén border. Considering the importance assigned to water management in Maya society, it is impossible to view this landscape and not consider the potential role that these minor but ubiquitous features may have played in supplying water.

The ability of small depressions to serve as year-round water storage features has been questioned due to their shallow depth and presumed high rates of evaporation (Scarborough 1998:144; Scarborough and Gallopin 1991:661), though actual evaporation calculations have not been made. We therefore entertained a theoretical input-output calculation, choosing the most shallow depression (No. 4) for which we hypothesize a water-holding function. The calculation in Table 3 is hypothetical and aims to show the dynamics of changing water tables in a water hole throughout several years. We would like to emphasize that there are many unknown parameters that may considerably influence any calculation of this kind. The immediate vegetation around a water hole can alter evaporation, and even more so aquatic plants growing on the water surface. The ancient Maya may have used aquatic plants in open reservoirs to purify the water (Lucero 1999:41) and retard evaporation through a reduction of water temperature on the surface (Matheny 1978:205). Additionally, evaporation in very small depressions could be considerably reduced by using covers.

Meteorological data were obtained from the National Meteorological Service of Belize. Precipitation measurements and minimum and maximum temperature readings come from Tower Hill Station in Orange Walk District, a very dry station located outside the study area. These data were used to calculate monthly input and evaporation (Table 3). For water consumption we have followed McAnany’s numbers used for a calculation for chultuns in the northern Lowlands. McAnany (1990:269) relies on a 2.8 liter daily water requirement given by the World Book Encyclopedia, but doubled this number to 4.8 liters per person per day in order to allow use of water not only for drinking, but also washing, food processing, manufacturing processes, and pot irrigation.

The calculations show that 47 people could have been supported year round with water if every person consumed 4.8 liters per day. If twice the amount (9.6 liters per person per day) were consumed, 23 people could have been sustained with water. During the rainy season a large surplus would have been available. Based on the same data 250 people (respectively, 125 people) could have used Depression No. 3. This quadrangular depression could be interpreted as household cistern, although its estimated capacity of 228,000 liters would support much more than one household group.

The calculations show that precipitation during the dry season (such as in January 1994) can keep water levels high with a sufficiently large catchment, even if annual rainfall is only 1419.8 mm as in 1993. Nevertheless, after a dry year, as in 1994 (1026.7 mm), low rainfall in January 1995 and hardly any rain in May 1995, the reservoir would have almost gone dry. We assume that such depressions would have been unable to provide dry-season supply as of A.D. 800, if climate indeed dried as much as suggested by various scientists (Curtis et al. 1996; Gill 2000; Gunn et al. 1995; Hodell et al. 1995, 2001). While the seasonal dynamics of reduced rainfall patterns are still unclear, a major reduction in January rains in the Terminal Classic (Messenger 1990:36) may have made it increasingly difficult to maintain rainy season surpluses through the dry season.

Small depressions could have been perennial water sources, but based on our sample size we cannot conclude that they alone would have served a major water supply role at the household level. Indeed many other small-scale sources should be considered such as storage in jars, ancient shallow wells (Robichaux 2000), and chultuns (Scarborough et al. 1995:109; Tourtellot 1993:8) as there is yet no general agreement as to their function. One should also consider various combinations of these storage possibilities. If water truly was a limiting factor during the dry season and the means were available to store abundant rainy season precipitation, a resourceful household would employ them in the absence of cultural prohibition. Such multistrategic behavior is also known from other areas of the world, where water forms a valuable resource (Wåhlin 1997). From our preliminary data the use of dispersed non-centralized water systems can only be demonstrated for the Late Classic period, but such storage behavior could have also existed at earlier time periods.
Table 3. Water Use Calculation for Depression No. 4.

<table>
<thead>
<tr>
<th>Month</th>
<th>Water Input(a)</th>
<th>Evaporation(b)</th>
<th>Consumption(c)</th>
<th>Net Storage(d)</th>
<th>Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>25,088</td>
<td>7,654</td>
<td>6,994</td>
<td>57,000</td>
<td>10,440</td>
</tr>
<tr>
<td>February</td>
<td>5,725</td>
<td>6,844</td>
<td>6,316</td>
<td>49,565</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>0</td>
<td>8,343</td>
<td>6,994</td>
<td>34,228</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>34,387</td>
<td>11,405</td>
<td>6,768</td>
<td>50,442</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>76,236</td>
<td>14,240</td>
<td>6,994</td>
<td>57,000</td>
<td>48,444</td>
</tr>
<tr>
<td>June</td>
<td>97,854</td>
<td>14,483</td>
<td>6,768</td>
<td>57,000</td>
<td>76,603</td>
</tr>
<tr>
<td>July</td>
<td>25,574</td>
<td>14,369</td>
<td>6,994</td>
<td>57,000</td>
<td>4,211</td>
</tr>
<tr>
<td>August</td>
<td>68,879</td>
<td>13,454</td>
<td>6,994</td>
<td>57,000</td>
<td>48,431</td>
</tr>
<tr>
<td>September</td>
<td>60,656</td>
<td>12,150</td>
<td>6,768</td>
<td>57,000</td>
<td>41,738</td>
</tr>
<tr>
<td>October</td>
<td>44,451</td>
<td>11,154</td>
<td>6,994</td>
<td>57,000</td>
<td>26,303</td>
</tr>
<tr>
<td>November</td>
<td>31,369</td>
<td>8,408</td>
<td>6,768</td>
<td>57,000</td>
<td>16,193</td>
</tr>
<tr>
<td>December</td>
<td>22,451</td>
<td>6,626</td>
<td>6,994</td>
<td>57,000</td>
<td>8,831</td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>47,539</td>
<td>6,780</td>
<td>6,994</td>
<td>57,000</td>
<td>33,765</td>
</tr>
<tr>
<td>February</td>
<td>28,142</td>
<td>8,092</td>
<td>6,316</td>
<td>57,000</td>
<td>13,734</td>
</tr>
<tr>
<td>March</td>
<td>10,653</td>
<td>8,861</td>
<td>6,994</td>
<td>51,798</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>2,256</td>
<td>11,834</td>
<td>6,768</td>
<td>35,452</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>14,262</td>
<td>14,831</td>
<td>6,994</td>
<td>27,889</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>41,189</td>
<td>15,147</td>
<td>6,768</td>
<td>47,163</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>37,094</td>
<td>14,378</td>
<td>6,994</td>
<td>57,000</td>
<td>5,885</td>
</tr>
<tr>
<td>August</td>
<td>36,747</td>
<td>13,811</td>
<td>6,994</td>
<td>57,000</td>
<td>15,942</td>
</tr>
<tr>
<td>September</td>
<td>65,930</td>
<td>12,304</td>
<td>6,768</td>
<td>57,000</td>
<td>46,858</td>
</tr>
<tr>
<td>October</td>
<td>24,255</td>
<td>11,899</td>
<td>6,994</td>
<td>57,000</td>
<td>5,362</td>
</tr>
<tr>
<td>November</td>
<td>37,337</td>
<td>8,699</td>
<td>6,768</td>
<td>57,000</td>
<td>21,870</td>
</tr>
<tr>
<td>December</td>
<td>10,861</td>
<td>7,136</td>
<td>6,994</td>
<td>53,731</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>6,246</td>
<td>6,691</td>
<td>6,994</td>
<td>46,292</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>5,899</td>
<td>6,245</td>
<td>6,316</td>
<td>39,630</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>4,164</td>
<td>9,234</td>
<td>6,994</td>
<td>27,566</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>18,599</td>
<td>14,499</td>
<td>6,768</td>
<td>24,898</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>104</td>
<td>17,909</td>
<td>6,994</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>62,911</td>
<td>17,132</td>
<td>6,768</td>
<td>39,110</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>99,242</td>
<td>14,766</td>
<td>6,994</td>
<td>57,000</td>
<td>59,592</td>
</tr>
<tr>
<td>August</td>
<td>83,454</td>
<td>16,459</td>
<td>6,994</td>
<td>57,000</td>
<td>60,001</td>
</tr>
<tr>
<td>September</td>
<td>59,302</td>
<td>13,146</td>
<td>6,768</td>
<td>57,000</td>
<td>39,388</td>
</tr>
<tr>
<td>October</td>
<td>82,690</td>
<td>12,191</td>
<td>6,994</td>
<td>57,000</td>
<td>63,505</td>
</tr>
<tr>
<td>November</td>
<td>29,565</td>
<td>9,501</td>
<td>6,768</td>
<td>57,000</td>
<td>13,296</td>
</tr>
<tr>
<td>December</td>
<td>21,930</td>
<td>7,768</td>
<td>6,994</td>
<td>57,000</td>
<td>7,168</td>
</tr>
</tbody>
</table>

\(a\) Precipitation in mm/month collected by catchment (380 m²) and depression surface (81m²) minus 30% for catchment seepage (see Scarborough and Gallopin 1991:Table 1).

\(b\) Monthly evaporation (using the Thornthwaite-formula, Withers and Vipond 1978:74).

\(c\) 47 people x 4.8 liters per day.

\(d\) Quantity of water available at the end of each month; the depression can hold 57,000 liters.

*Based on data from 1992 (annual precipitation 1471.5 mm) we calculated that by the end of December 1992 the water hole would still be full.

Perhaps some burden of proof should be shifted to those who suggest a lack of family-level water storage strategies. Indeed, considering the broad ramifications of such behavior, perhaps ideas of centralized water management should not be supported without first being able to reject alternative decentralized water sources.

Acknowledgments. The work reported here was performed under permits extended to Fred Valdez Jr. for the Programme for Belize Archaeological Project and Norman Hammond and Gair Tourtellot for the La Milpa Archaeological Project. Research under the PIBAP was funded by the Austrian Science Foundation (FWF-projects P12256-SPR and P12953-SPR). The research under the LaMAP was funded by a Sackler Scholarship from Boston University, from funds donated by
Raymond and Beverly Sackler. We would like to thank the Department of Archaeology of Belize for permitting these studies and the Meteorological Service of Belize for supplying meteorological data. Special thanks go to the following people without whose support this research would not have been possible: Laura Levi, who integrated the research into her field studies, Fred Valdez Jr., who organized and supported participation in the Programme for Belize Archaeological Project, and Norman Hammond and Gair Toutellott, who invited and supported further research on depressions under the La Milpa Archaeological Project. Kerry Sagebiel and Lauren Sullivan have provided invaluable help in analyzing and dating ceramics. Our thanks also go to all the students who have helped with mapping, excavation, and laboratory work. We would like to thank Miguel Angel Carretero for correcting the Spanish abstract and Patricia Fournier, Norman Hammond, Jon Lohe, Katharina Schreiber, Gair Toutellott, Steven Weiss, and five anonymous reviewers for their comments on earlier versions of this paper.

References Cited

Adams, Richard E. W.
Bullard, William R.
Carr, Robert F., and James E. Hazard
Coe, William R., and William A. Haviland
Covich, Alan P.
Curtis, Jason H., David A. Hodell, and Mark Brenner
1996 Climate Variability on the Yucatan Peninsula (Mexico) during the Past 3500 Years, and Implications for Maya Cultural Evolution. Quaternary Research 46:27–47.
Dahlin, Bruce H., and William J. Litzinger
Dominguez Carrasco, María del Rosario, and William J. Folan
Dunning, Nicholas P.
Dunning, Nicholas P., Timothy Beach, and David Rue
1997 The Paleoclimatology and Ancient Settlement of the Petexbatun Region, Guatemala. Ancient Mesoamerica 8:255–266.
Dunning, Nicholas P., Vernon L.Scarborough, Fred Valdez, Jr., Sheryl Luzzadder-Beach, Timothy Beach, and John G. Jones
Folan, William J.
Folan, William J., Joyce Marcus, Sophia Pincemin, Maria del Rosario Domínguez Carrasco, Laraine Fletcher, and Abel Morales López
Gill, Richardson B.
Gómez-Pompa, Arturo, José Salvador Flores, and Mario Aliphat Fernández
Gómez-Pompa, Arturo, José Salvador Flores, and Victoria Sosa
Gunn, Joel D., William J. Folan, and Hubert R. Robichaux
Hammond, Norman, and Gair Toutellott III
Hammond, Norman, Gair Toutellott III, Sara Donaghey, and Amanda Clarke
Harrison, Peter D.
Haviland, William A.
Hodell, David A., Mark Brenner, Jason H. Curtis, and Thomas Guilderson
Hodell, David A., Jason H. Curtis, and Mark Brenner
Hughbanks, Paul J.


Hunter-Tate, Clarissa C.

Jennings, Joseph N.

Kepecs, Susan, and Sylviane Boucher

Lene, Gene W.

Lewis, Brandon S.

Lohe, Jon C., and Patrick N. Findlay

Lucero, Lisa J.

Maler, Teobert

Matheny, Ray T.

Maudslay, Alfred P.

McAnany, Patricia A.

Messenger, Lewis C., Jr.

Miksicek, Charles H.

Puleston, Dennis E.


Reina, Ruben E., and Robert M. Hill

Rice, Prudence M.

Ricksten, Oliver G.

Robichaux, Hubert R.

Sagebiel, Kerry L.

Scarbrough, Vernon L.


Scarbrough, Vernon L., Matthew E. Becher, Jeffrey L. Baker, Garry Harris, and Fred Valdez, Jr.

Scarbrough, Vernon L., Robert P. Conolly, and Steven P. Ross

Scarbrough, Vernon L., and Gary G. Gallopin

Siemens, Alfred H.

Smith, A. Ledyard

Tourtellot, Gair III
1993 A Critique of the Water Management Hypothesis. Manuscript on file, Department of Archaeology, Boston University.

Tourtellot, Gair III, and John J. Rose
Season. Manuscript on file, Department of Archaeology, Boston University.
Tourtellot, Gair III, Amanda Clarke, and Norman Hammond
Tourtellot, Gair III, John J. Rose, Nikolai Grube, Sara Donaghey, and Norman Hammond
Tozzer, Alfred M.
Valdez, Fred, Jr.
Wählin, Lars
Weiss-Krejci, Estella
Withers, Bruce, and Stanley Vipond

**Notes**

1. Lucero (1999:39) developed a model of seasonal mobility to solve the disparity between the hypothesis of seasonally concentrated water sources and the dispersed Classic Maya settlement pattern.

2. For the purpose of this study we defined their size from approximately 7-to-722 m². The lower limit is set by the smallest depression at Tikal, the upper limit is marked by Depression B at La Milpa East. This depression is still smaller than any depression that is considered a permanent reservoir at La Milpa and Kinal (see Scarborough et al. 1995, 1994).

3. At Tikal small depressions enclose between 7-and-420 m². Thus they are considerably smaller than central precinct and bajo-margin reservoirs but only slightly smaller than residential reservoirs and unmodified aguadas. The residential Madeira reservoir has a surface of ca. 2,000 m² and Aguada Subin ca. 500 m².

4. All depressions have been renumbered for the purpose of this discussion. If not mentioned in the text, their original numbers and provenience are given in Table 1.

5. Mayanists in general distinguish between hard caprock and the lower soft sascab (e.g., Dunning 1992:20; Lohse and Findlay 2000:180). We apply a finer scale: (1) very hard caprock, which can be perforated with a pick only with difficulty; (2) hard caprock, which can be perforated with a pick, but not with a trowel; (3) medium-hard bedrock, which can be picked and scraped with a trowel; (4) soft bedrock or crumbly sascab, which can be easily removed with a trowel; (5) powdery sascab, which can be removed by hand. These differences may help to identify the origin and function of depressions.

6. Calcite 5–10, dolomite 0, mixed layer (clay minerals) 60–80, quartz 10–15, amorphous (noncrystalline) 10–20 (values represent mass-percent). The clay sample from RB-60, Suboperation A, Lot 9 was analyzed at the Arsenal Research Center, Vienna, Austria.

7. Neither Tepeu 1 nor Tepeu 3 ceramics have so far been encountered in closed deposits in the area around La Milpa. The earliest Late Classic deposits at La Milpa have a mixture of Tepeu 1 and early facet Tepeu 2 ceramics. These so called Tepeu 1/2 deposits contain sherds that date between A.D. 600–750. Tepeu 2/3 deposits contain sherds that date between 750–850. These deposits have late facet Tepeu 2 and some Tepeu 3 sherds (Sagebiel 2002).

8. Gray layer RB-56, Suboperation F, Lot 5; calcite 75–85, dolomite 15–25, mixed-layer (clay minerals) < 2, quartz < 2, amorphous (noncrystalline) 0. Bedrock RB-56, Suboperation F, Lot 7: calcite 60–70, dolomite 30–40, mixed-layer (clay minerals) < 2, quartz 0, amorphous (non crystalline) 0. Values represent mass-percent. Analysis by Arsenal Research Center, Vienna, Austria.

9. Annual rainfall between 1993 and 1995 at Tower Hill was 1,270.9 mm. This is lower than the mean annual rainfall of 1,350–2,000 mm generally given for the central Maya lowlands (Scarborough and Gallopin 1991:659), but still higher than the 1,000 mm of the Puuc hills (McAnany 1990). Annual evaporation averaged 1,678.9 mm.

10. According to Scarborough, who cites evidence from East Africa, humans require 2–3 liters of water per day in a sedentary economic environment (Scarborough 1991:102). On the other hand, a modern family in the Edzná Valley uses 16.6 liters during the dry season as opposed to 8.6 liters during the wet season. Washing clothes is excluded from this number, but adults take at least one bath each day, and small children are even bathed more often (Matheny 1978:204).

11. Evidence of this is also provided from several shallow Mennonite cattle tanks in the area, which have not been dry for several years.

Submitted February 6, 2001; Accepted May 25, 2001; Revised January 29, 2002.