11 Lake Khufu: On the Waterfront at Giza – Modelling Water Transport Infrastructure in Dynasty IV

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Introduction

In Year 26–27 of Khufu's reign, a man named Merer with the title *śḥḏ* (inspector) led a team (*sꜣ*, phyle) of workers as they made round trips by riverboat delivering fine limestone from the eastern quarries at Tura (*R ʿw*) to the construction site of *ꜣḫt Ḫwfw* (the 'Horizon of Khufu'), the Great Pyramid. We know this from pieces of Merer's logbook, a major part of the Wadi el-Jarf Papyri that the IFAO/Sorbonne team under the direction of Pierre Tallet discovered between 2011 and 2013 (Tallet 2013; 2016; 2017).

We learn from this amazing textual window onto the Memphite landscape and the building of the Great Pyramid that the team transited an area called either *Š-Ḫwfw* (Lake, or Basin of Khufu) or *R-š Ḫwfw* (Port of the Lake of Khufu), where they would often spend the night. Tallet (2016:18) suggests these places or installations served 'le rôle d'un point de relais sur la route de Giza, au terme d'une journée de navigation', as well as being points of administration for the royal building project. The papyri also mention the *Š ꜣḫt Ḫwfw* (the Basin of Akhet Khufu – that is, of the Great Pyramid), the *Ḏnt nt R-š Ḫwfw* (Dyke of the Ro-She Khufu), as a point of anchorage and safe haven for a fleet,[1] the *ḫmw n Aḫt Ḫwfw* (chapels of Akhet Khufu), a settlement called *ʿnḫ Ḫwfw* (Vive Khufu) and an elongated structure called *sḫꜣt nt Š-Ḫwfw* ('Beak of the Basin [or of the Lake] of Khufu').[2] These 'précieuses indications "visuelles" sur le site' (Tallet 2017:113) in Merer's log turn our attention again to the interface between river, valley floor and high desert at Giza, to the general Memphite zone during the heyday of pyramid building during Dynasty IV and to the ongoing issue of pyramid harbours.

For 30 years I have been trying to understand and reconstruct the Dynasty IV floodplain and water transport infrastructure at Giza (Lehner 1985a; 2009; Ziegler 1999). In recent years I pulled together what I have learned to once again try to model Dynasty IV waterways at Giza, as a heuristic exercise. Sources of information gleaned over the decades include interventions in the Giza floodplain for modern building; trenches and core drillings for a waste-water system (AMBRIC 1989); AERA excavations at the Heit el-Ghurab site, at Khentkawes Town and in the Menkaure Valley Temple; the contours of the floodplain as captured in 1977 by photogrammetry in the Ministry of Housing and Reconstruction (MHR) map series at scale 1:5000; core drilling; survey and excavation by colleagues at Giza, Abusir, Saqqara, Dahshur and Memphis; and studies of the Nile River and its navigation in Egypt. I drew on these sources to model the river, floodplain and water transport infrastructure at Giza in Dynasty IV (Fig. 11.1).

I contoured the model with values that reflect my best estimate for the elevations of principal features in meters above sea level (m asl) as follows:

16.00+:	'dockside' at the edge of the low desert	
		Khentkawes I basin edge
		base of the Menkaure Valley Temple glacis
		terrace north of the Wall of the Crow
		bedrock quay east of the Sphinx Temple and Khafre Valley Temple
15.00–16.00:	low desert settlement and infrastructure (Heit el-Ghurab)	
14.50–15.00:	'dockside' farther east into the floodplain	
		Khufu Valley Temple
		Zaghloul Street Wall
14.80s:	river bank settlement (attested in AMBRIC cores and trenches)	
13.50–14.50:	the water surface at flood peak	
12.00–12.50:	floodplain	
10.00:	deepest flood basins	
7.00–7.50:	low water in basins and channels	

These values cohere between different sorts of evidence, between core drill logs and actual exposures of Dynasty IV architecture and settlement, and between Giza and reconstructed 'spot heights on the landscape' from Memphis to Dahshur (Lehner 2009).

In what follows I try to explicate the sources and evidence for my most recent model of the Dynasty IV floodplain as transformed by the pyramid builders, beyond the brief summary and sample that I have previously published (Lehner 2014b).

Part I: The Pyramid Harbour

Before dealing with specific evidence and issues on which I base my most recent model of Dynasty IV water transport infrastructure at Giza, I review the question about

Figure 11.1 Map of Egypt showing the location of the main areas and sites mentioned in the paper of the main areas and sites mentioned in the paper and the Dynasty IV water transport infrastructure at Giza with contour values in metres above sea level. White indicates low water level at 7 m asl (graphic by Rebekah Miracle from AERA GIS based on design by Mark Lehner).

pyramid harbours in light of the discovery in the last ten years of harbour-like basins at south Dahshur and southeast Giza.

It is an old idea that harbours fronted onto valley temples at the lower end of the long causeways that lead up to the pyramids on the high plateau. It was supposed that canals must have delivered Nile water into these harbour basins, at least during the flood season (late August through October), if not during low Nile (December to June). Thus Borchardt (1907: sheet 1) drew Nile floodwaters lapping up around the valley temples of the Sahure and Niuserre pyramids, and I.E.S. Edwards used the same image in successive editions of his popular introduction *The Pyramids of Egypt* (1993 [1947]:154, fig. 35). Georges Goyon (1971; 1977:131–9) believed a western canal supplied water to harbours fronting all the valley temples of the Old and Middle Kingdom pyramids from Hawara and El-Lahun at the Fayum entrance to Saqqara, as well as to a great river port of Memphis with an outlet there into the Nile. He saw the old canal known as the Bahr el-Libeini as the continuation of this Memphite canal on its bend northwest, from Abusir to Giza and Abu Roash, so servicing valley temples of the pyramids at these sites (Goyon 1971:150, n. 6). Goyon imagined water lapping up against the terraces fronting the Khafre, Unas and Pepi II valley temples. In his map of '*le port*' in front of Khentkawes Town and the Menkaure Valley Temple, he shows Nile water extending to the eastern front of these layouts, and to the north face of the Wall of the Crow, which he takes as a dyke (Goyon 1971:145, fig. 5; 1977:136, fig. 42). Since Goyon wrote, we have found that the Wall of the Crow is as wide as it is tall (around 10 m) and that the builders left enormous banks of construction debris on both sides, features which do make the wall somewhat like a dyke (Lehner and Tavares 2010:176–7).

In the early 1990s, Giddy (1994:195–6) reinforced this vision of the early landscape. She based her view on Survey of Memphis results up to that time. Jeffreys and Tavares (1994:156, 159) suggested that natural desert-edge lakes might have provided water to the fronts of the valley temples, replenished during the seasonal inundation, or accessed by a channel corresponding to the old Libeini channel. They understood lakes still showing in recent years as vestiges of ancient reservoirs, either natural or modified harbours. They expressed the opinion that, while the valley temples of the middle Saqqara range of pyramids have never been located, the valley temple of Unas was certainly a functioning harbour (Jeffreys and Tavares 1994:156). Like Goyon (1971), they believed the old Libeini Canal was 'a residual subsidiary channel serving the new Fifth-Dynasty valley temples wherever this was feasible' (Jeffreys and Tavares 1994:159).

Core drillings done in following years diminished the idea that the valley temples were functioning harbours, as opposed to *simulacra* harbours, because the sediments were not what the investigators expected from the bottoms of flooded basins (Jeffreys 2001; 2008; Casey 1999:25). Also, the elevations of the temple floors, terraces and the bases of the walls and approach ramps, as far as then known, seemed much too high for the best estimates of the Nile flood maxima or floodplain levels (Seidlmayer 2001:47–8). It was assumed that if valley temple floors were several meters above the floodplain, or above the flood maximum, they could not have fronted onto harbours.

Our findings north of the Wall of the Crow during seasons 2001, 2002, 2004, 2005 and 2006 appeared to confirm that no Nile water ever reached the Menkaure Valley Temple or Khentkawes Town (Lehner 2009:129–36). Our work between 2004 and

2006 north of the Wall of the Crow, about 300 m due east of the Menkaure Valley Temple, exposed parts of a terrace that the Dynasty IV builders formed out of compact limestone rubble (Lehner *et al.* 2006). We exposed the terrace for a distance of 30 m north of the gate in the Wall of the Crow. Our archaeological trenches, core drilling, and a contractor's trench cut to a depth of 2 m below this terrace showed layers of sandy gravel and marl (*tafla*) clay – material we might expect to have been deposited by desert wadi floods or by standing water at the mouth of the wadi between the Moqattam and Maadi Formation outcrops at Giza.

We found the terrace here to be around 16.30 m asl, sloping down gradually to the north and east. This is well above my best estimate for the Dynasty IV floodplain (12.00–12.50 m asl). We found no edge of a channel or basin. I therefore rejected the idea that a harbour or Nile floodwater extended west as far as the Menkaure Valley Temple or Khentkawes Town, concluding that 'the evidence points not to an artificially-excavated embayment, basin, or harbor, rather to a landing on the Nile bank [hundreds of metres] east of the Menkaure Pyramid' (Lehner 2009:136).

A Consilience of Discoveries

A consilience of discoveries at Giza and Dahshur prompted us to reconsider the conclusion that basins immediately east of the pyramid valley temples could not have received Nile water. The discoveries certify that that the pyramid builders did, in fact, dredge dramatically the mouths of wadis to create harbours east of the valley temple of Sneferu's Bent Pyramid in south Dahshur and east of Khentkawes Town. During 2009 and 2010, work at both sites revealed lower approaches that ended to the east in deep, artificially quarried depressions or basins with bottoms at a level commensurate with the best estimates for the Old Kingdom floodplain. Pyramid builders might have used these basins as harbours. At both south Dahshur and Giza, the western ends of the basins are located 1 km west of the nearest possible desert/floodplain border or former location of a Nile channel. These discoveries raise the question: did pyramid builders excavate channels deep into the wadis that connected the basins to the floodplain?

During 2009 and 2010, members of the Dahshur mission of the German Archaeological Institute and the Free University of Berlin excavated the continuation of a mudbrick causeway that slopes five degrees down to the east from the so-called 'valley temple' of the Bent Pyramid. This causeway lay buried deep under the sand overburden. They cleared the causeway for a length of 141 m to a U-shaped rectangular basin that extends 95 m north–south and 145 m east–west. Mudbrick retaining walls line the basin on the west, south and north. Geophysical survey indicated an enclosing wall on the east. A drilling (B133) toward the centre, eastern end of the basin still hit only sand at 13.18 m asl (Alexanian and Arnold 2016:5), meaning that the basin must be yet deeper. An elevation of 23 m asl on the top of the retaining wall near the southwestern corner shows the basin is more than 9.82 m deep. Another drilling (B81) a little farther north to a depth of 13.60 m asl did not hit the natural *tafla* bottom. At that level, the drill went through a layer, about a metre thick, with *tafla*, clay, ceramic, limestone, shell and wood fragments. Two other drillings to the west, toward the centre of the basin, reached 13.80 and 14.58 m asl without hitting bottom. The bottom of the basin appears to step down continuously toward the centre (Alexanian *et al.* 2010:6; Alexanian *et al.* 2012:22–7; Alexanian and Arnold 2016).

The point where the German mission members detected the bottom of the basin at 13.18 m asl is between 800 m and 1 km up the wadi from the desert/cultivation border, if we take that border as the Dahshur Canal[3] – the German mission's core drillings indicate that the sand stretched much farther east in ancient times from the contemporary desert/flood plain border. Geophysical survey gave indications for a canal shortly east of the basin, but not farther east. In drill hole B81 east of the basin they reached the natural shale wadi bottom at 13.80 m asl (Alexanian and Arnold 2016:5). The excavators cite an estimate for the Old Kingdom flood level at Memphis and Saqqara of 13.00–14.00 m asl and a maximum 14.50–15.50 m asl (Jeffreys and Tavares 1994:157–8; Seidlmayer 2001:47; Lehner 2009:136–42; Alexanian and Arnold 2016). With this estimate, they can imagine Nile floodwaters reaching nearly 1 km west into the wadi, perhaps with the help of feeder canals, dams and a collector basin opening from the wadi mouth onto the floodplain.

The Khentkawes Basin

Between 2009 and 2011 the AERA team found the northern end of a terraced basin at Giza east of Khentkawes Town. The basin is the central feature of a previously unknown lower approach up to the causeway that leads to the Khentkawes Monument. This ascent includes ramps, stairs and corridors along the northwest corner of the basin (*AERA Annual Report* 2011:6–11; Jones 2011; Lehner 2011b; 2011c; 2011d; Lehner *et al.* 2011:160–5; *Aeragram* 2012:10–13). On the east bank of this basin we found the Silo Building Complex (*Aeragram* 2011; 2012; 2014). Here, from late Dynasty IV into Dynasty V, people stored grain, baked bread and accounted for their production in a layout similar to the Khentkawes Town houses.

We have cleared the northern end of the Khentkawes basin. The southern part lies under a modern road and cemetery. We hypothesise that the Khentkawes basin is the northern of two prongs of an L-shaped basin (Fig. 11.1 above), and that a western prong extended to the bottom of a glacis below the eastern Annex of the Menkaure Valley Temple (Lehner 2015c:282, fig. 6.12; 2015b:247, fig. 21). This is the farthest west that the Dynasty IV engineers could extend their water transport infrastructure at Giza (Lehner 2014c:72; 2014d:21–2). However, we cannot be certain of these two prongs, because the split lies under the modern cemetery. The broad ramp between the Menkaure Valley Temple Annex and the southern end of Khentkawes Town (Lehner 2011a:63–70) probably begins at the corner between the basins, but again because of the cemetery we are able to map only the upper, western part of this ramp.

Builders created the sides of the Khentkawes basin by banking limestone quarry debris to form two terraces at elevations 16.03 and 14.90 m asl (*Aeragram* 2014:2–5; Lehner 2014a). In core drillings across the northern end of the basin we hit the lowest (deepest) bottom farthest to the centre, at 11.37 m asl. With the annual flood peaking at 14.00–14.50 m asl (Lehner 2009:142), the basin would fill to a depth of 2–3 m, deep enough for boats, but only during flood season (Lehner 2011b). During low water at 7–7.5 m asl, this basin would remain dry (Lehner 2014b:22). If a channel delivered Nile water to the Khentkawes basin, at least during the inundation, it must have come in from the east at some point south of our exposure, once again somewhere under the modern road and cemetery, because we found no opening in what we exposed of the eastern bank of the basin. Rather, to the east in our clearing, we found the Silo Building Complex, founded upon an artificial bank composed of limestone quarry debris.

The Khentkawes basin is 300 m west of the eastern end of the Wall of the Crow and 450 m west of our easternmost exposure of the Heit el-Ghurab settlement. These benchmarks on the Dynasty IV landscape lie to the south of a direct line from the Menkaure Valley Temple and Khentkawes Town to the east. The basin also lies 750 m west of the modern Mansouriyah Canal, which has been suggested as following the line of a very early, possibly pre-Old Kingdom Nile channel, and about 1.6 km west of the old Libeini Canal, also often suggested to be a relic of a former Nile channel (Bunbury *et al.* 2009; Lehner 2009:109–10; Butzer *et al.* 2013:3344–50, fig. 2b). Any watercourse coming into the central eastern delivery zone at the low southeastern base of the Giza Plateau had to make a great bend to get around the projecting spur that supported the Heit el-Ghurab settlement and the Wall of the Crow (Lehner 2009:140), not unlike the great bend from south to north-northwest passing North Saqqara and into the Abusir basin.

So, at both Giza, east of Khentkawes, and at Dahshur, southeast of the Bent Pyramid lower temple, we now have artificial basins. At Giza, the artificial basin lies in the mouth of a wadi between the Moqattam and Maadi Formation outcrops. At south Dahshur, the artificial basin lies 800 m west of the mouth of the main wadi. Pyramid builders quarried both basins to the depth of the floodplain (which has always been higher at Dahshur, 14–20 km south of Giza, because of the northward longitudinal slope of the floodplain). Both basins lie 800 m to 1 km west of the nearest possible location of the river/flood plain in the Old Kingdom. The idea that Nile water could never have reached the valley temples may be true, but the water certainly could have arrived at the easterly, lower extensions from these temples – the secondary causeway east of the valley temple of the Bent Pyramid, and the lower approaches east of the Khentkawes Monument and Menkaure Valley Temple.

Part II: Three Geomorphologies: Prerequisites for Modelling Water Transport Infrastructure at Dynasty IV Giza

Pyramid builders needed to adapt three broad features of the Dynasty IV Giza landscape to install their water transport infrastructure: (1) the shape of the bedrock and access up onto the plateau; (2) the central wadi, which divides the Moqattam and Maadi Formation outcrops; and (3) the scale and position of any Nile river channel(s) that ran east of the Giza Plateau.

Many of the effects of pyramid building on the Giza Plateau are visible, thanks to large-scale excavations at the beginning of the last century. However, sand fills the central wadi separating the Moqattam and Maadi Formation outcrops, hiding the depth and form of the wadi. The positions of the Nile channel(s) in the Old Kingdom are not at all obvious, although scholars have suggested that visible topographical features mark old river channels, in particular the old Libeini Canal that today runs alongside and west of the modern Marioutiyah Canal.

The Hard Rock Gateway to Giza

The Giza Plateau presented only one major access to deliver massive quantities of Tura limestone and granite blocks to the pyramids and upper temples (Fig. 11.2). Merer and his men had to come in at the low southeastern base of the pyramid plateau proper, along the lines that I illustrated in 1985 (Lehner 1985a; 2007a), adapting Thomas Aigner's (1981; 1982; 1983a; 1983b) publications about Giza geology and geomorphology. Here, I review those features pertinent to water transport infrastructure on the valley floor.

The Giza Plateau is one of a series of high limestone 'saddles', separated by tectonic depressions filled with unconsolidated sediment (Wagner 1935). These pyramid promontories belong to the Abu Roash complex, a group of geological formations left by forces that folded the large rock masses in Cretaceous and Eocene times. The major pyramid fields at Abu Roash, Giza and Saqqara correspond more or less to these stratified arcs of folded bedrock (Aigner 1982:381–2). Two limestone formations outcrop at Giza. The local outcrop of the Middle Eocene Moqattam Formation, named after the Moqattam Hills northeast of Cairo, forms the pyramid plateau proper, providing quarries (the holes) and foundations for pyramids (the piles). At Giza, the Moqattam Formation outcrop drops suddenly in two stepped cliffs on the north-northwest and slopes gently to the south-southeast. The three pyramids and most of the Giza Necropolis occupy the surface of this gentle slope, which disappears into the low desert on the south and southeast.

The younger, Upper Eocene, Maadi Formation rises as a series of knolls south of the pyramid plateau proper, beyond the 'central wadi'[4] that separates the two formations (Fig. 11.2). The bedding (strata) of the Maadi Formation can be seen in the quarried knoll, known locally in Arabic as Gebel el-Qibli (the 'Southern Mount'). The knoll rises to about 60 m asl, roughly the same elevation of the Khufu Pyramid, and towers above the mouth of the central wadi south of the Sphinx (Fig. 11.2). The Gebel el-Qibli forms the end of the ridge facing east and running south at roughly this elevation.

At Giza, the Moqattam Formation slopes rather evenly about three to six degrees from a high point west of the pyramids, 105.80 m asl, to the accumulated sandy overburden, 23 m asl, in the area between the Sphinx and the Wall of the Crow. In Dynasty IV, before this sand accumulated, the Moqattam Formation met the low desert sand at an elevation between 15 and 16 m asl, a drop of 91 m. Khufu's builders founded his pyramid at 60 m asl, so the drop to any dockside bedrock was about 44 m. The Dynasty IV floodplain, at 12.00–12.50 m asl (Lehner 2009:142), lay 3–4 m lower, stretching to the east across the valley.

The Moqattam Formation escarpment thrusts up to 45 m asl north of the Sphinx and continues north as a steep cliff. The Khufu causeway crossed the escarpment at about this elevation, 45 m asl (Lehner 1985a:120, fig. B6; see Fig. 11.2). In Dynasty IV, the cliff and the low desert sloped down another 30 m to between 14 and 14.5 m asl at the Khufu Valley Temple (Lehner 2009:105). The 30 m-high cliff curves around north of Khufu's Pyramid to continue to the northwest. Builders covered the north escarpment with massive tip lines of debris, waste from their stone cutting and building (Lehner 1985a:124, fig. B24; see also Petrie 1883:213).[5]

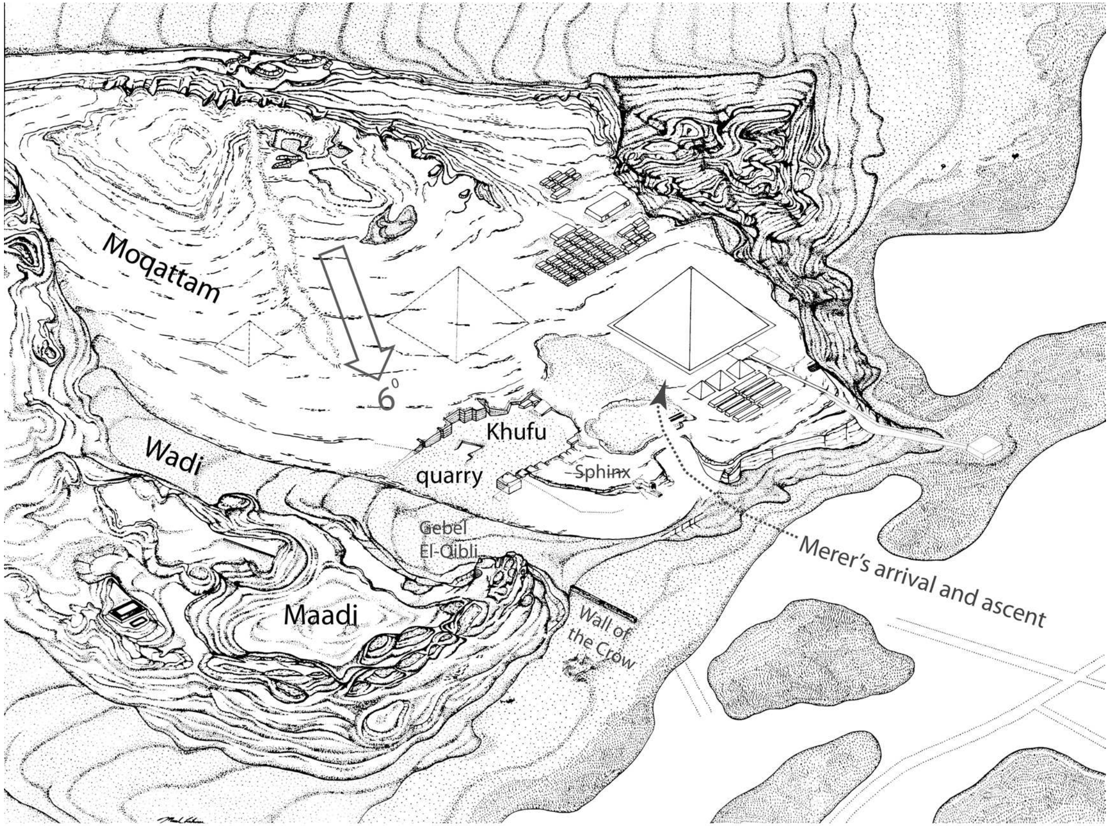

Figure 11.2 Isometric drawing of the Giza Plateau with features resulting from the Khufu Pyramid project, showing the six-degree southeasterly dip of the Moqattam Formation outcrop and the Maadi Formation. I reconstructed the original width of the wadi by extrapolating from this dip, and the eastern cliff line of the Moqattam Formation as crossing the position of the Sphinx (Lehner 1985a:119, fig. 3B). However, the spot immediately northeast of the Sphinx would be the most efficient access up to the Khufu Pyramid, arriving at its southeastern corner (dashed line). Access to Khufu's main quarry, which furnished local (as opposed to Tura) limestone for the Khufu Pyramid, lay farther south, through the central wadi.

Immediately north and east of the Great Pyramid, only the following options existed for Khufu's forces to deliver material from the valley floor to the base of his pyramid: Khufu's causeway embankment and the builders' own dumps. Of course, their dumps increased as the pyramid rose, and may have proved sufficient to support an ascent later in the project. Then, builders could form a track on the debris, similar to the modern road up to the Khufu Pyramid from the end of Pyramids Road and the Mena House Hotel. The road runs upon this ancient debris on a cut into the pyramid builders' dumps.

In recent decades, the Egyptian government has cut further into this debris to widen this road. In 2004, west of the road, they cut the Rowad Trench (so-named after the contractor), 60 m long × 30 m wide × 10 m deep, to place the current administrative buildings, ticket counters and gated entrance. With the Giza Inspectorate, AERA team members recorded the cross-sections through the stratified dumps of the Great Pyramid builders. At around 40 m asl, the deposits consisted mostly of fine powder and small chips intercalated with layers of large limestone fragments. The strata showed the sequence of stone work on the pyramid. The fragments appear to consist mostly of the finer limestone of the pyramid's outer casing, and the stone debris contained a variety of material culture, including organic materials that did not persevere in the lower (15–16 m asl) and damp Heit el-Ghurab settlement site (Lehner 2015b:61, n. 315).[6] While Dynasty IV builders might have maintained a ramp up onto the plateau upon this debris, this was, without doubt, not the major delivery point. The rise is very steep, and most deliveries of building stone – limestone from Tura and granite from Aswan – would have come to Giza from the south-southeast. For the most part, the entire escarpment north and northwest of Khufu's Pyramid served more to eject waste from, rather than deliver material to, the pyramid project.

As Merer's log so generously reveals, pyramid builders brought building stone by boat from the south and east. Along the whole of the eastern escarpment of the Giza Plateau, including both the Moqattam and Maadi Formation outcrops, the only natural break is the broadened mouth of the central wadi – that is, the tectonic depression filled with unconsolidated sediment (Wagner 1935; Aigner 1982) that separates the two outcrops. By necessity, because of the hard, bedrock geomorphology, for three generations of Dynasty IV pyramid building and landscape transformation, the principal delivery zone lay east of the gateway formed by the southern end of the eastern Moqattam Formation escarpment – that is, the northern ledge of the greater Sphinx amphitheatre, and the northern end of the Maadi Formation, the Gebel el-Qibli.

Engineering Wadi Mouths

The Dynasty IV pyramid builders massively transformed the central wadi gateway to Giza. In particular they drastically excavated the bottom and cut back the sides of the wadi. With the area to the east as the delivery zone, and the wadi as the main gateway to the local quarry and up onto the plateau (Fig. 11.2), the edges of its bed must have been used for delivery tracks (Lehner 1985a:127, fig. 3C).[7]

We understand wadi mouths opening onto the Nile Valley as places of *aggradation*, because episodic desert flooding flushes out sand, gravel and desert clay, forming raised terraces on alluvial fans at the wadi mouths. Wadi fans have been taken as platforms for settlements that stayed dry above the annual inundation, especially in early Egypt (Kemp 2006:75, fig. 21; Sampsell 2003:33; Bunbury 2009:54–5). Given the convexity of the Nile floodplain, the flood was deepest near the desert edge (Butzer 1976:15–16), where the wadi fans stood above the Nile floodplain. Silt-rich, forceful, Nile inundations might raise and expand the floodplain until it once again covered the wadi fans, after which wadi floods, in turn, washed out more desert material to raise their fans above the silt. Such cycles left silt interleaved with desert sand and gravel layers (Branton 2010; Dufton and Branton 2010).

In order to create basins deep into wadis, like those found recently below and east of the valley temple of the Bent Pyramid and below and east of Khentkawes Town, the pyramid builders needed to first excavate the natural wadi fans composed of desert sand and gravels. They could use the material as fill in ramps and embankments, if not in the pyramids themselves. The recent excavations in the wadi east of the Bent Pyramid's valley temple at Dahshur and in the Giza central wadi east of Khentkawes Town reveal that the Dynasty IV builders excavated both the natural fill and the underlying bedrock of these wadis. Their deeper excavations into the natural limestone or *tafla* layers served as catchments for flash floodwaters running down the wadi. Rains were, perhaps, more frequent in the early Old Kingdom (Butzer 2001b:5; Butzer *et al.* 2013), increasing the number of wadi floods. Quarry catchments afforded protection for settlements and infrastructure farther down the wadi slope at the edge of the floodplain.

Dynasty IV Engineering in the Southern Dahshur Wadi

In Dahshur the ancient builders excavated deep into the natural *tafla* 'bedrock'. They shored up the sides of their excavation with thick mudbrick walls to form the western end of an enclosed depression more than 1 km up into the wadi from its opening onto the low desert or floodplain. From this basin to the floodplain, they may have dredged the wadi floor and regularised its width, 100–200 m. They also straightened the sides of the wadi along a course 1100 m long (Alexanian *et al.* 2008:4; Alexanian and Arnold 2016:4).

The German mission carried out geomorphological profiling of the head of the branch wadi in which Sneferu's builders founded the upper causeway of the Bent Pyramid. Their profiling shows how the pyramid builders transformed this branch wadi to make the upper limestone causeway (Bebermeier *et al.* 2011:336–7, fig. 6b). While they did not reach the bottom of the lower trunk wadi with the mudbrick causeway and the basin (Alexanian *et al.* 2012:22–7), trenches that they excavated in the lower wadi show how Sneferu's builders cut through the bedrock *tafla* and shored up the sides of their cut for the basin with massive mudbrick retaining walls and debris fill (Bebermeier *et al.* 2011:336–7, figs. 5–6, 346; Alexanian and Arnold 2016).The investigators see sandy loam and loamy sand units in the greatest depth of their drill core B27, far toward the west end of the artificial basin, as evidence that Nile flood events reached this far west into the wadi (Bebermeier *et al.* 2011:336).[8]

At Giza, it is certain that builders transformed the central wadi in major ways. This is obvious from the 10 m tall pedestal of the Khentkawes I monument, preserved in Moqattam Formation bedrock. The bedrock pedestal stands as a *coupe témoignage* at the edge of a huge-scale quarrying operation, where the Dynasty IV builders removed much of the northern bedrock side of the wadi (Lehner *et al.* 2011; Lehner 2015c:215–18). They built the Khentkawes I valley complex into a deep cut into the bedrock, and ramps ascend to Khentkawes Town against a vertical, east-facing quarry wall. Here, as in the newly found lower basin at south Dahshur, the builders retained the edges of the deeper basin with mudbrick walls, albeit they are not so massive as at Dahshur.

On the southern side of this wadi, it was probably the Dynasty IV builders who cut the Gebel el-Qibli, the knoll of the Upper Eocene Maadi Formation, leaving its northern side as a quarried semi-circle curving east–west. I had begun to doubt how much of the Gebel el-Qibli cut is artificial (the rock is highly brecciated and falls of its own accord), and how much of the cut dates to Pharaonic times. Recently, we have seen remains of Late Period burials, including amphorae, in deep recesses in the northeastern face of the knoll, suggesting that the truncation of the knoll is older than the Late Period.[9] Deep sand and the modern Muslim and Coptic cemeteries fill the wadi bed between the Gebel el-Qibli and Khentkawes Town and the Menkaure Valley Temple. But from the top of the Gebel el-Qibli, or from the top of the Khentkawes Monument, we can see that the modern tombs still follow the dip of a subtle trough running under the cemetery. This dip probably marks the main, deep channel of the wadi.

East of Khentkawes Town, our excavations have revealed how deep the Dynasty IV Egyptians excavated the wadi fill and quarried the underlying bedrock. Their deep intervention here is some 300 m to the west-northwest of the Wall of the Crow. The dramatic quarrying of the northern side of the central wadi extends much farther west up the wadi, and much deeper, as shown both by the Khentkawes I pedestal and by the southern extension of the Central Field West quarry (the 'Cheops-Chephrensteinbruch' – Jánosi 2005:301–2), which furnished most of the core stone for the Khufu Pyramid (Fig. 11.2 above).

Butzer et al. *(2013) on the Giza Central Wadi*

Ignoring the huge-scale, anthropogenic transformation of the central wadi, the so-called 'Menkaure Wadi', is a major failing of Butzer *et al.* (2013), when they suggest that desert floods through this wadi repeatedly damaged Dynasty IV infrastructure on the Heit el-Ghurab site. They write that '[n]ext to the repeated flood destruction of the Workmen's Town, the most salient environmental event at Giza was the wholesale transport of sandy wash out onto the floodplain during OK times' (Butzer *et al.* 2013:3364), and Butzer has further stated that 'there were severe climatic perturbations during the Dynasty IV, when sustained heavy rains liquefied mudbrick or fed surges of the wadi which descended from near the Menkaure pyramid and repeatedly swept destructively through HeG' (Butzer 2016:71). These authors say nothing about the glaring, obvious, large-scale, anthropogenic transformations of the wadi and its eastern mouth, which most probably prevented this wadi flowing with flash foods during the Dynasty IV occupation of Heit el-Ghurab.

When he joined our fieldwork in 2001, Karl Butzer was enormously insightful about the significance of our exposures at Heit el-Ghurab as an environmental record in the greater context of geomorphology and climate studies at Giza and beyond (Butzer 2001a; 2001b), because Heit el-Ghurab occupies an interface of wadi, low desert and floodplain. Butzer and his co-authors carried out their fieldwork with the AERA team in 2001 and 2002, but they did not join us in the field for the next decade prior to publishing their article in the *Journal of Archaeological Science*. We did not see a draft of their article before publication, and many detailed comments and corrections are required to set the value of this article against its mistakes and omissions, and to bring it into line with 12 years of excavation and research subsequent to the authors' fieldwork at Giza. I will only touch on a few salient points that relate to the central wadi at Giza.

We do not see the repeated wadi floods damaging, catastrophically,[10] the Heit el-Ghurab site as in the narrative that Butzer and his co-authors develop from the information they gathered during their fieldwork, and from the extent to which they did refer to and incorporate publications of our work at Heit el-Ghurab, Khentkawes Town and the Menkaure Valley Temple between 2002 and 2013. Much of their narrative about wadi flooding is based on sections that Butzer drew in the two large backhoe trenches (BBHT-1 and BBHT-2) at the northeast part of the site (Butzer *et al.* 2013:3351, fig. 8, 3356, fig. 13). Butzer and co-authors specify, at one point, that they use the term 'formal Gallery' to 'designate the earliest […] mudbrick structures, which were rebuilt many times in the NE sector of the Workmen's Town' (Butzer *et al.* 2013:3353).However, they use this term as a rhetorical device to generalise observations from the backhoe trenches in the far northeastern part of the site to the whole of the Gallery Complex.

In fact, the backhoe trenches lie outside the Gallery Complex. Our excavations within the Gallery Complex, before and after 2002, which, in 2012, included another complete gallery (Gallery III.3 – see *Aeragram* 2015:12–16), have not shown the multiple flood destructions and rebuilding of the Butzer *et al.* (2013) narrative.[11] In 2006, AERA team members redrew, more accurately and at a larger scale than Butzer's on-site sketches, the entire section of both BBHT-1 and BBHT-2. The northwest-facing part of the BBHT-1 section, toward the southern end of the trench, was particularly influential: the authors observed the top of a thick mudbrick wall that seemed to have been frozen in the process of having its top melted and which flopped over to the northern side (Butzer *et al.* 2013:3351, figs. 8–9). The wall features as event/stratum 7 in the authors' fig. 9, and they saw 'sludge' between the walls. Above the melted wall, the section showed remains of a limestone structure – possibly a rebuild (which does not appear in the authors' figs. 8–9).

During AERA's 2006 season, to test the very ideas about that section that Butzer had discussed with the team on-site in 2001–2002, we excavated the very same wall as shown in the authors' figs. 8–9. We excavated stratigraphically from top down in our Square 4.N24 (Lehner *et al.* 2009b:32–5, fig. 18). We did not see multiple rebuilds of that thick wall (our feature number 26,025). Instead, as in a number of our excavation areas, we saw two major phases, not multiple rebuilds. Unusually thick walls of mudbrick comprise the lower phase in Square 4.N24, and the very wall identified as their event/stratum 7 was largely intact at its base. A catastrophic wadi flood during the time people occupied the site would have cut the walls first from the bottom, causing them to topple, and then dissolve the mudbrick to sludge.

In an upper, later phase in Square 4.N24, water had indeed 'melted' the remains of limestone structures, 'whether it be from the flooding of the Nile or from the Wadi' (Hassan weekly report 16xi06, quoted in Lehner *et al.* 2009b:32). And through this upper phase, we recorded sinuous, sand-filled channels. But this whole northeastern zone was soaked and saturated from repeated Nile flooding that took place long after the Dynasty IV occupation, well into the beginning of the twentieth century. I believe that any wadi flooding effects were local to the northeast part of the site, along the zone where the northeastern corner of the Dynasty IV settlement was wiped out and replaced by deep sands. This removal was post-occupation, and Nile floods played a role.

Even though Butzer and colleagues (Butzer *et al.* 2013; Butzer 2016) ignore the obvious, massive Dynasty IV quarrying of the wadi mouth and northern flank of the wadi, it might well seem that these transformations would augment wadi floods, and so reinforce their narrative.[12] But deep quarrying can also create flood traps and catchments, and quarrying was not the only engineering of the central wadi.

The central wadi starts on the west just below and north of the high point called the Panorama, which is a stop for tourists, souvenir hawkers and camel touts. Here, the wadi is but a little gully, and until recently[13] one could stand with one foot on either side. Facing east, down-wadi, you could similarly place your right foot on the Maadi Formation, and your left on the Moqattam Formation. From here to the east, until south of the Menkaure Pyramid, the wadi widens and is encumbered by sand. However, much of the surface of the Moqattam Formation bedrock is exposed along the northern side, and a low shelf of Maadi Formation bedrock is exposed low on the southern side, close to the wadi bed. Until this point, the wadi shows hardly any channel. The light grey Moqattam Formation surface simply slopes down under the yellowish-brown Maadi Formation outcrop.

South and southeast of the Menkaure Pyramid, the wadi broadens into a wide swale, filled with sand, south of the horseshoe-shaped quarry of the Menkaure Pyramid (Reisner 1931:9, 69 for the quarry). The southern segment of the thick field stone 'peribolus' wall, as Petrie (1883:114–16) called these outer enclosure walls, runs through the centre of this swale (Fig. 11.3). A gap in the eastern end of this stretch of wall opens to the low southern rim of the Menkaure quarry. It is possible that the pyramid quarrymen created this swale, and that it served as a catchment for rainwater and wadi flooding. When we walked the site in 2001, Karl Butzer himself suggested the Egyptians might have used quarry bottoms to trap water that they could use for making mortar and other purposes. Such a catchment would impede flooding further down the wadi.

A little farther east, the fieldstone peribolus wall turns in an acute elbow to head north in the direction of the Khafre Pyramid (Saleh 1974:132–3, fig. 2). Builders founded this stretch on a massive embankment of quarry waste debris. On the south, the embankment and the elbow of the peribolus wall touches a curving berm of quarry debris that the pyramid builders dumped over Maadi Formation bedrock (Fig. 11.3). We can see the composition of the debris under a light sand cover, thanks to paths worn by horse riders. Just here, Abd el-Aziz Saleh mapped a series of three more embankments, 2–2.5 m thick, along the base of the Maadi Formation outcrops, connected in a rough C-shape open to the northwest (Fig. 11.3, dashed line) toward the wadi, for a total length of 450 m (Saleh 1974:132, fig. 1, 147–8). The western segment runs along the base of the Maadi Formation knoll forming the southern flank of the wadi, and the eastern embankment runs southeast to northwest along the west side of the berm to form a constricted opening with the elbow wall to the north. It appears that here the Dynasty IV Egyptians were 'river training' the wadi.[14]

In order to flow farther east, water would have to fill the swale on the west and spill over the berm and spur of dumped quarry debris. I think this highly unlikely. Here Dynasty IV builders constricted the wadi. With the berm, embankment and spur

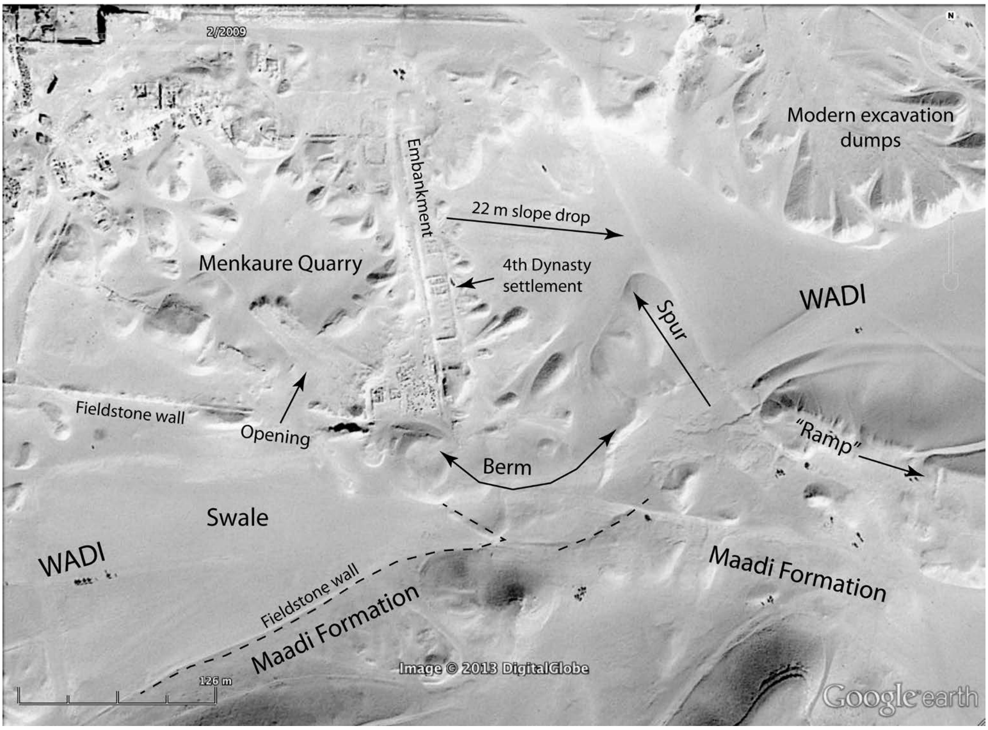

Figure 11.3 The central wadi at Giza, showing the juncture of the Dynasty IV Menkaure quarry settlement excavated by Saleh (1974) along a thick fieldstone wall, a berm of cultural debris across the course of the wadi and a northward thrusting spur of quarry debris over the edge of the Maadi Formation. The northern run of the fieldstone wall and settlement are founded upon an embankment of quarry debris. From here, a sheer slope falls 22 m to the east (image from Google Earth, February 2009).

they effectively dammed any episodic flooding. Also, downslope they had yet another safeguard for Heit el-Ghurab against the threat of wadi floods.

From the northward-running embankment that supports the Dynasty IV buildings, the wadi drops 22 m (from 47 to 25 m asl), south of the Menkaure causeway (Figs. 11.3–4). Where the causeway crosses the western edge of the Central Field West quarry, excavations by Cairo University in 1980 showed dramatic, terraced, deep quarrying of the bedrock, with bright red quarry lines, measurements and a Dynasty IV work gang graffito. These markings quickly faded and disappeared.

At the base of this steep slope, below the western face of the Gebel el-Qibli, geophysical survey of the wadi shows a large sand-filled cavity, possibly more than 10 m deep (Dash 2004:8–9). This large depression extends to just before the westernmost of Serena Love's drill cores, DC61 (Fig. 11.4). The depression is certainly a deep quarry, and it would have caught any wadi floodwater that managed to flow this far to the east. From here the overall direction of the wadi turns northeast to bypass the Menkaure Valley Temple and Khentkawes Town, and then the wadi turns east to its broad embouchure between the Wall of the Crow and the Khafre Valley Temple. The total length of the wadi is about 2.5 km from the Panorama to this opening.[15]

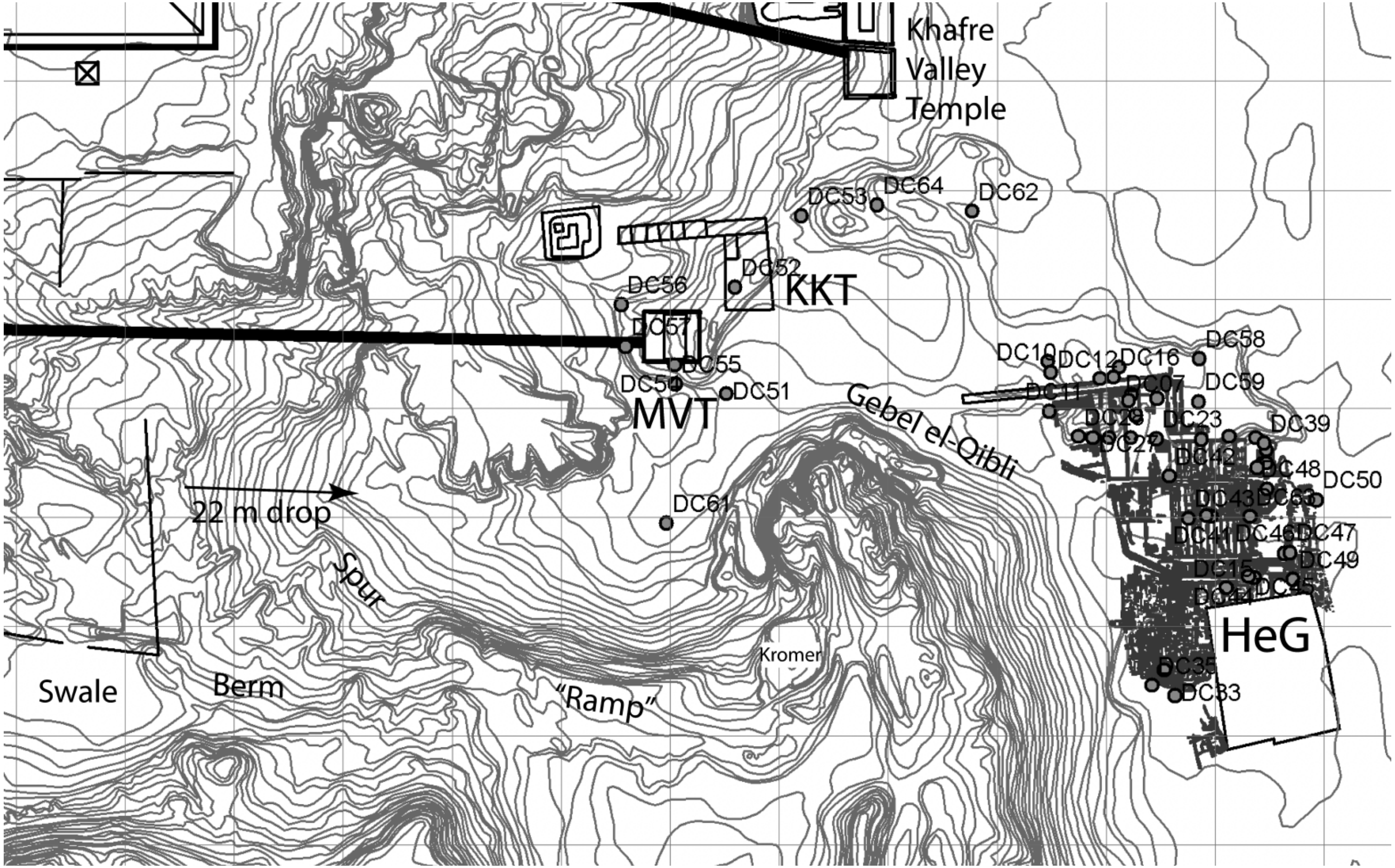

Figure 11.4 Central wadi contours (as of 1977), the Menkaure Valley Temple (MVT), Khentkawes Town (KKT), the Heit el-Ghurab site (HeG) and the 2002 drill cores.

Butzer *et al.* (2013:3362, fig. 20) show channels of the central wadi (in their terms, 'the Menkaure Wadi') cutting diagonally, northwest to southeast, across the northeastern part of the Heit el-Ghurab site. If this were the main channel, it would have to make a C-shaped bend, nearly 180°, around the base of the Gebel el-Qibli. However, their fig. 2C (Butzer *et al.* 2013:3345; also in Butzer 2016:71, fig. 5), labelled 'Old Kingdom Giza', shows the main line of the 'Menkaure Wadi' heading east-northeast instead of turning south-southeast across Heit el-Ghurab, as in their fig. 20. The truer axis of the wadi *is* east-northeast, as in their fig. 2C. But, given the extent to which the Dynasty IV Egyptians transformed the wadi, it is questionable that it flowed with water, as opposed to flowing with quarrymen and haulers, during the reign of Menkaure.

We do see an erosional cut through the Gallery Complex off the eastern end of the Wall of the Crow (Lehner 2002:52–3). Our excavation of this feature in 2001 and 2002 influenced Butzer *et al.* (2013) to think that wadi flooding repeatedly damaged Heit el-Ghurab. Either natural or human forces cut into galleries from 3 to 5 m east of the east end of the Wall of the Crow and removed all but the lowest 20 cm of the gallery walls. Later during the Dynasty IV occupation, people dumped waste from working granite and diorite – chips, fragments and dust – to block this cut. The thick layer of granite waste lies directly over a low bench or dividing wall, a rectangular fireplace, an *in situ* pottery vat and the highest of a series of marl floors between the remains of gallery walls. In 2002 we hypothesised, together with Butzer and co-authors, that a flash flood had washed from north of the Wall of the Crow, and turned southeast to make this cut. However, it is then curious that the stream of water left intact the small structures upon the floor, namely the low bench and fireplace.[16]

Initially, I was attached to the hypothesis that wadi flooding made the cut through the galleries, after which people filled the cut with the granite-rich bank of debris, 85 cm to 1.3 m thick (Lehner 2002:52, n. 33). This hypothesis is still viable. But it is improbable, for reasons stated above, that the water streamed all the way through the wadi from its beginning on the high plateau. Rather, if rushing water cut the northern gallery wall, it was localised, like cuts in sand banks and other deposits that we have seen in several parts of the Giza Necropolis after torrential rains.

In 2006 Lisa Yeomans re-examined the cut and excavated the granite fill (Lehner *et al.* 2009b:19–20). She found that the western side of the cut is rectilinear, with a flat bottom four brick courses up from the base of the wall. Three courses of *in situ* mud bricks line the cut on the east. The trenches Yeomans excavated perpendicular to the north face of the northern gallery wall did not support the idea that water flowed up against this wall.[17]

This is not to discount the wadi floods that cut through the Menkaure Valley Temple, as Reisner (1931:44–5) documented, or the flood that cut a small canyon – 'the Cut' - through the northern side of the broad ramp between the Menkaure Valley Temple and Khentkawes Town (Lehner 2010; 2011a:72–7, 88–92, foldout 4) or the flooding that carved a wide gully through the northern enclosure wall and terraces of the Khentkawes basin (Lehner *et al.* 2011:174, fig. 21, 179). These were localised events, specific to the northern shoulder of the wadi.

The Menkaure Valley Temple and Khentkawes Town, conjoined by the broad ramp, perch on the northern shoulder of the wadi, not in its swale or bed. As mentioned, we can make out the lowest wadi channel in the dip of the modern cemeteries that cover the wadi mouth. As Butzer *et al.* (2013:3357), following Reisner (1931:44–5), recognised, the streams of water that damaged the Menkaure Valley Temple and Khentkawes Town started in a shallow gully that descends from highest part of the plateau northwest of the Menkaure Pyramid. The gully runs past the northwest corner of the Menkaure Pyramid and then down the north side of its causeway.[18] Also, these flash floods came a generation or more after Menkaure. Flooding cut the gullies through the Menkaure Valley Temple and Khentkawes basin wall after the middle of Dynasty V (Lehner *et al.* 2011:180), and it was probably in Dynasty VI that a combination of natural floods and peoples' channelling formed the large aforementioned 'Cut' through the broad ramp between the Menkaure Valley Temple and Khentkawes Town (Lehner 2011a:178–81).

When Menkaure's builders founded the Menkaure Valley Temple and the eastern, foot-end of Khentkawes Town (Lehner *et al.* 2011:146–54), they closed off much of the northern shoulder of the wadi, which builders had long used for deliveries to the pyramid projects. The lowest, central part of the wadi channel, such as the Dynasty IV quarrymen left it, must pass close to the southern side of the Menkaure Valley Temple. We cannot be certain, because it lies buried under sand. Love's core drilling DC61 hit *tafla* that appeared to be bedrock between 15.37 and 14.4 m asl (Fig. 11.4 above). This bedrock must be the upper edge of the deep cavity indicated by geophysical survey (Dash 2004:8–9), if that cavity can be proven. The hard *tafla* was covered by sand and silty sand layers with burnt shell at 17.09 m asl, charcoal at 16.76 m, and 'gray silt balls' at 16.31–15.37 m, just above the apparent bedrock floor (Love 2002, II:95–7). This grey silt could derive from Shepseskaf's works to complete the Menkaure Valley Temple and Khentkawes Town in mudbrick (Lehner 2015c:239). The cultural material suggests human activity, perhaps on the tracks that builders must have made for delivering materials for the pyramid projects.[19] If the deep cavity in the wadi west of the Gebel el-Qibli can be proven, then after the pyramid builders quarried it to some depth, they would have had to skirt its northern edge to lay any hauling tracks leading toward the pyramids (Lehner 2015c:237, fig, 16).

Butzer (2016:75) keeps to his narrative of catastrophic 'Menkaure Wadi' flooding when he wrote: 'Eolian sand is inconspicuous in the open context of the Menkaure wadi, where it was largely flushed out by occasional spates.' This is a bit startling, because the deep depression indicated by electromagnetic conductivity survey in the broadest part of the wadi, perhaps as much as 10 m deep, is probably filled mostly with sand (Dash 2004:8–9). As a non-specialist, I accept that it may take professional analysis in the laboratory to distinguish eolian from fluvial sand, but repeated wadi flushing would have removed both. Drill core DC61 penetrated more than 6 m of sand from around 24 to 17.09 m asl.

A River Ran Through It – Where?

The position and size of the Nile River channel(s) is the first and most unanswered question for modelling water transport infrastructure at Giza. Where flowed a Nile channel east of Giza in Dynasty IV? We can identify five possibilities: (1) major Nile channel east (as today); (2) major Nile channel east, subsidiary channel west; (3) major Nile channel west; (4) major Nile channel west, subsidiary channel east; or (5) two or more major channels, 'head of the Delta' south of Giza.

The Nile Geoform

Scholars have discussed migrating Nile channels and pyramid harbours with insufficient consideration of the overall geomorphology of the Nile, its floodplain and the practical, physical implications for water transport infrastructure. Here I summarise my understanding of Nile geomorphology in Egypt.

Every year, rain in the East African highlands sends a colossal wave of water through the Nile basin. Before engineers dammed the Nile at Aswan, between late June and November water rose in the Egyptian Nile from 6–7 m above its lowest level in the main channel during late spring and early summer: from the Middle Ages to recent centuries, the difference between low and high water averaged 7 m in the Cairo area (Willcocks and Craig 1913, I:294, II:533).

The main Nile channel measures 10–14 m deep. Barois (1889:12) stated the channel near Cairo measured 12–15 m deep, where wharfs and other artifices narrowed the main channel to 240 m. Channel width varied greatly at any place, depending on the season: 'During mean [flood] stage the Nile flows bank full, with a width between banks from 500 meters to 2 kilometers, and is often divided into many channels by islands, which are frequently many kilometers long' (Barois 1889:12). Willcocks (1889:18) gave a mean width at flood of 1000 m, with 450 m minimum and 2000 m maximum flood width.[20]

In recent centuries, low water stood 5–6 m below the level of the floodplain near the Delta apex, and 8–10 m lower than the fields near Aswan (Barois 1889:12). Starting in late summer, the Nile wave began to move through the Egyptian valley. It inundated adjacent basin lands, usually not by overflowing the banks,[21] which rose 1–3 m higher than the adjacent valley floor. At 'plenitude' (Cooper 2014:108),[22] people unblocked the heads of seasonal navigation canals and 'feeder canals' that watered the basins, allowing water to surge through openings 3–4 m deep in the Nile levees (Willcocks 1889:53; Butzer 1976:46–37; Cooper 2014:117–23).[23] During the twentieth century, there was a yearly period of between six and eight weeks during which the basins held water 1–3 m deep, an average of 1.5 m (Willcocks 1889:44; Willcocks and Craig 1913, I:305). Clay and silt – basically disintegrated East African mountain material – settled at the bottom, enriching the basin bottoms for highly productive farming.

The Nile has always built up its levees higher than the adjacent valley floor. The land slopes down away from the levees, so that the lowest land is farthest from the river along the border with the low desert (Barois 1889:13). When the main Nile channel runs toward the centre of the valley, the result is a convex floodplain, like the spine of an overturned leaf (Richards 1982:14), a spine nearly 2 km wide. However, when the main channel runs close to one side of the valley, the land slopes down to the opposite side. The lateral slope of the convex floodplain is most pronounced where the valley is widest (Barois 1889:13)

The rise of natural levees was gentle, averaging 1 m above the field land (Barois 1889:13); but Nile levees could rise up to 3 m above the lowest alluvial basin and extend up to 200 m wide (Bunbury *et al.* 2009). As of 1977, in the latitude of Memphis, the floodplain between the Saqqara escarpment and the Nile rose from around 18+ to 22+ m asl along the Nile channel. As Butzer (1976:16) noted, the levees 'have been further raised and reinforced by artificial embankments that serve as longitudinal dikes to contain the river'. The dykes and embankments of recent centuries have ranged to over 13 m wide at their base and 3–5 m wide at their top (Willcocks and Craig 1913, II:519–20).

The combination in flood season of increased river depth, velocity and width, with more frequent and stronger northerly winds, made the flood season – August through October – the optimal, indeed the only practical, period for large cargo boats (Cooper 2014:116–17, 128–32).[24] The dates given by the Wadi el-Jarf Papyri indicate that Merer's team made round trips from Tura to Giza from July to November, spanning the season of optimal navigability of the Nile (Somaglino 2015:143; Tallet 2017:91, 160, citing Cooper).

For studies of land management and irrigation in ancient Egypt, we need to consider the transverse slope, which is more pronounced than the longitudinal slope, south-to-north, of the Nile Valley (Alleaume 1992:302–4). For pyramid harbours, the transverse slope, and the position of the major Nile channel(s), was critical. When the Nile migrated laterally, the shift of its levees must have changed the entire lateral slope and convexity of the flood plain. Thus, when we think of migrating Nile channels (Lutley and Bunbury 2008), we have to think of the physical immensity of levees and lateral slope moving with it.

Pressed Against the West? Flipping the Floodplain

The hypothesis that Old Kingdom Egyptians might have excavated artificial basins in front of valley temples in natural bays, such as the Abusir embayment, and in wadi mouths, such as the Khentkawes basin in the mouth of the central wadi at Giza, or even farther west, like the basin up into the southern wadi at Dahshur, and the idea that these basins could have received Nile water, at least during inundation, must come to terms with the hypothesis that a major Nile channel ran close against the desert along the western side of the valley in the Early Dynastic and Old Kingdom.[25]

If the main channel plus its levees comprised a landform 1.5–2 km wide, and if the main channel was located toward the western wide of the valley in the Early Dynastic and Old Kingdom Memphite zone, it would have filled the entire area between the Saqqara escarpment and the western side of the Memphis ruin mounds, causing us to wonder if high bank land supporting Early Dynastic and Old Kingdom settlement between 15–16 m asl in both ribbon zones, attested in core drilling and other evidence published by the Survey of Memphis,[26] could be contemporary settlement on the two levees of the same Nile channel in the Third Millennium BCE (Lehner 2009:102–4).

At first thought, it might make sense that the closer the main Nile channel was to the pyramid valley temples, the better for delivering water into the low desert bays, wadi mouths and basins in front of these temples. But I would like to suggest that the main Nile channel on the west would have been as much bane as boon for this task. While a Nile channel pressed close to the Western Desert would have brought the main source of water close to these basins, it would have also formed a massive bulwark against the direct delivery of that water into those basins. Why would this be so? What does a main Nile channel pressed against one side of the valley look like? The Nile of today gives us an idea at the very latitude from Saqqara to Giza.

At the latitude of Giza, from the last century until present, the Nile has flowed against the eastern side of the valley,[27] leaving the lateral slope entirely to the west with total difference in elevation of 4–5 m from the river bank to the western floodplain edge of as of 1977, when the photogrammetry and plotting of the 1:5000 MHR series captured the slope in 1 m contour intervals (Lehner 2009:100–2, pl. 4). The 4–5 m rise of the floodplain due to the silt deposited by the annual inundation over the centuries[28] since Dynasty IV just about equals the difference between the lowest floodplain land and the higher land of the Nile levees in recent times. If the floodplain of 4500 years ago showed an equivalent lateral slope as that of 1977, we might imagine that as the main Nile channel migrated east, the annual siltation over the centuries that built up the floodplain would average out and bury the former western levees, leaving only subtle, linear ridges in the contemporary topography, such as the three ridges that Bunbury *et al.* (2009:158–9, pls. 38–9) hypothesised as relic river levees: two ridges west and east of the Mansouriyah Canal, which runs along the former low desert-floodplain border (Reisner 1942: pls. 5a, 6) and a third ridge along the Marioutiyah and Libeini canals (Lutley and Bunbury 2008).

At the end of the nineteenth century, Willcocks published a profile of the valley just at the latitude of Saqqara and Helwan (Fig. 11.5, taken from Willcocks 1889:19, pl. 7; reproduced in Willcocks and Craig 1913, I:367, fig. 26). The purpose of this illustration was to show the flood surface in this zone, 50 km above the barrages at the Delta head, compared with another cross-section 600 m above the barrages.[29] The level flood line shows the highest levee land on the east against the rise of the desert.

We can use Fekri Hassan's (1997:60, fig. 2) schematic version of this profile to 'flip' it from east to west, to see how the main Nile channel and its levees might configure when on the far west of the valley, between the Saqqara escarpment and what is now the western side of the Mit Rahina ruin mounds (Fig. 11.6).

The MHR 1:5000 map sheets showing the contours of the Nile Valley document a 4–5 m rise of the 1977 floodplain from the ribbons of low land east of Giza (top), which mark older channels, at 16+ and 17+ m asl, to the eastern Nile levee (Lehner 2009:100–1, colour pl. 4, here greyscale Fig.11.7). With the Nile against the eastern side of the valley, the entire floodplain slopes down to the lowest land at the far west, against the Western Desert.

While we do not know that the exact same metrics obtained for a Nile channel on the far west of the valley in the Old Kingdom, it may be instructive to visualise the reverse situation by flipping the 1977 contours and aligning the course of the Nile approximately to that of the Libeini (Fig. 11.8). Flipping the modern floodplain at the latitude of Giza and dropping the contour values by 4–4.5 m puts the entire floodplain on a lateral slope down to the lowest land at 12.00–2.50 m asl on the far eastern side of the valley. Depending how close the main Nile channel was to the western escarpment, a western main channel would have left little or no room for a floodplain between the river and the desert. The high western bank would have pressed against the desert, the inverse of recent times.

In this exercise, the desert/river bank interface to the southeast of the Giza Pyramids – that is, the location of Heit el-Ghurab – would be around 15–16 m asl (Fig. 11.8). In fact, the settlement ruins range in elevation between 15–16.5 m asl. In the reconstruction, the bank land along the river is somewhat lower, 14.00–15.00 m asl. It is just within this metre of elevation – generally around 14.80+ m asl, with an average of 14.74, that we find Old Kingdom structures or evidence of settlement in core drillings east of the Giza Plateau (Lehner 2009:110–11, 142).

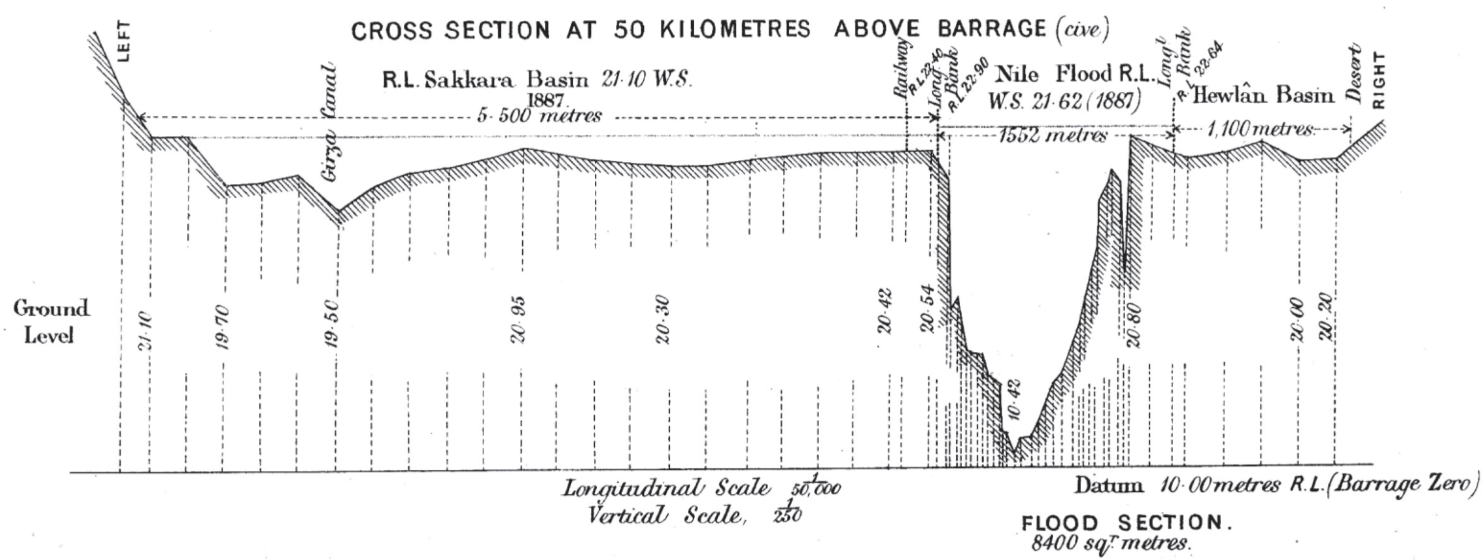

Figure 11.5 Cross-section of the main Nile channel and the valley floor at the latitude of Saqqara (left, west) and Helwan (right, east), with exaggerated vertical scale (from Willcocks 1889:19, pl. 7).

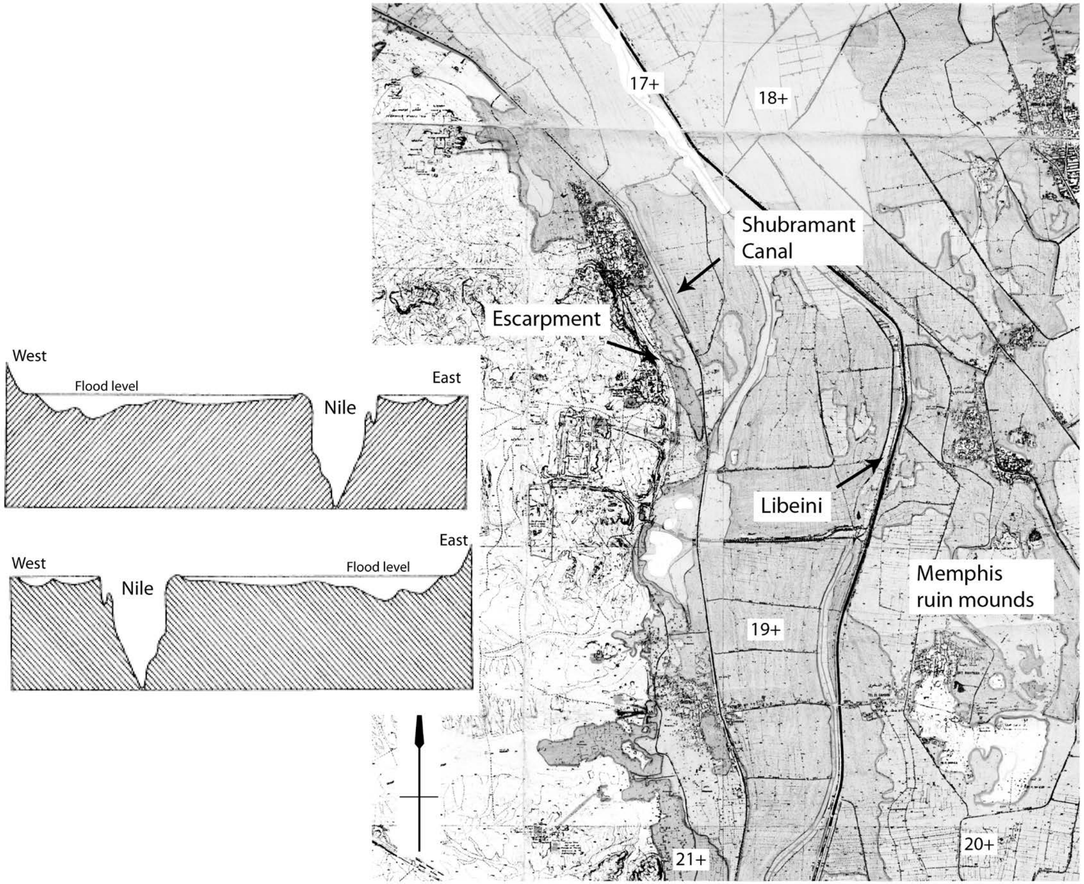

Figure 11.6 Implications of a western main Nile channel in the Saqqara-Memphis corridor. The Nile plus its levees would fill the distance, 1.6 km, between the Shubramant Canal and the Libeini, or the area between the North Saqqara escarpment and the western side of the Memphis ruin mounds. Most of the floodplain, and the lowest floodplain land, would have been on the eastern side of the valley, as illustrated by reversing the profile of the valley as published by F.A. Hassan (1997:60, fig. 2).

Figure 11.7 1977 MHR map of the floodplain east of Giza to the Nile, with shaded 1 m contour intervals between 16+ to 21+ m asl. The entire floodplain forms a lateral slope away from the main Nile channel on the far eastern side of the valley to the lowest land on the far western side of the valley. For colour version, see Lehner (2009:100–1, colour pl. 4).

Figure 11.8 An exercise in reconstructing a main Nile channel on the far west and high levee land between the river and the Giza Plateau in Dynasty IV. The map and contours of the valley floor at this latitude are reversed and the main Nile channel placed along the course of the Libeini. The absolute values for the Old Kingdom contour intervals would be, according to our best estimates, about 4–4.5 m lower than the modern values, so that the lowest land, 16+ m asl, would be 12+ asl. The reversal puts the entire floodplain on a lateral slope to the lowest land on the eastern side of the valley at 12.–12.5 m asl. Note that the reversal makes the low desert meet Nile bank land to the southeast of the Giza Pyramids. This is the location of the Heit el-Ghurab site (HeG), which would lie between 15 and 16 m asl. In actuality, the Old Kingdom settlement ruins range in elevation between 15 and 16.5 m asl (graphic by Alexandra Witsell).

But what does linear bank land, pressed close against the western desert, do for watering the Khentkawes basin, located 1 km west up into the quarried mouth of the central wadi, with a bottom at 11.37 m asl, below the estimated Old Kingdom floodplain (12.50 m asl)? What are the implications of a main Nile channel on the west for the Lake (Š) of Khufu mentioned in Merer's journal?

At low water, the Nile channel would have acted like a deep moat, the bottom holding only shallow water, if it was not nearly dry. Just before each inundation, people had to haul any water from the bottom of the channel up over banks 7 m high. A deep Nile channel and its levees would have stood like a low-water moat between the necropolis and any residual water, far to the eastern side of the valley, at the bottom of the lateral slope.

Main Nile Channel on the East, Secondary Channel on the West?

After years of the Egypt Exploration Society's Survey of Memphis working from the hypothesis of an early main Nile channel on the west, migrating over time to the east, Hassan (2010) proposed an alternative model of river location and migration in the area from Memphis to Giza during early Egypt. Here we consider the implications of a main Nile channel on the east, as today, with a smaller, subsidiary Nile channel on the west.

According to Hassan, 'during the late Predynastic/Early Dynastic times, the Nile ran along the eastern margin of the floodplain. This accounts for the presence of key late Predynastic/Early Dynastic sites on the eastern bank of the Nile close to the desert edge at Heliopolis, Maadi, Tura, and Helwan' (Hassan 2010:6). Hassan based his model on an interpretation of Google Earth imagery and his own coring program in collaboration with Roger Flower and Mohamed Hamdan.

Similarly, Butzer *et al.* (2013:3344) state: 'Despite claims to the contrary [Lutley and Bunbury 2008], the main Nile channel at this latitude was more or less in its present position throughout Holocene times.' Butzer (2016:74) has further argued, with regard to the 'largest, suballuvial channel trace' in the Giza district, that 'this large sinuous channel only qualifies as a branch, although it is the largest such feature found in the boreholes', referring to the AMBRIC (1989) logs (discussed below). He states that 'subsurface geology simply does not allow' that 'the main Nile channel itself passed at the foot the of Giza Plateau some 5000 years ago' (citing Lutley and Bunbury 2008 and Bunbury *et al.* 2009)

Hassan sees the Libeini as the vestige of a secondary western Nile branch, a continuation of the Middle Egyptian Nile tributary, the Bahr Yusuf. Referring to Goyon's (1971) idea that along this course ran a canal linking the Bahr Yusuf to the Giza Pyramids and the western Delta, Hassan observes: 'This secondary channel was subject to disappearance periodically and to drying out during the winter. Accordingly, it was most probably maintained as a transport and irrigation canal' (Hassan 2010:137). In this passage Hassan does not specify when this channel was so maintained – was it in the Old Kingdom? He continues (Hassan 2010:138):

> In the model proposed here, the western branch of the Nile moved eastwards, while at that time the Main Nile channel moved to the west (as did the Nile since the seventh century AD). The movement of the river to the west was arrested after the foundation of Memphis. […] The movement of the Nile, which has also been detected through geophysical prospecting, [back] from west to east would have started soon after the reign of Pepi I.

In Hassan's model, we still see a former riverfront at Mit Rahina in the difference between the higher elevation of the First Intermediate Period cemetery and Middle Kingdom settlement at Kom Fakhry and the 1–4 m lower elevation of the New Kingdom layouts founded immediately to the east upon silt layers (Jeffreys 1985:50–1; Jeffreys and Tavares 1994:158–9; Aston and Jeffreys 2007:137). This riverfront, Hassan suggests, marks the limit of the *westward* migration of the main, *eastern* Nile channel from a position farther to the eastern side of the valley. This movement was arrested, he surmises, by the foundation of Memphis in the reign of Pepi I. Then, according to Hassan, this main eastern Nile channel tracked back east, and later west again.

For Giza, Hassan relies on Hawass's assessment that that the Wall of Khufu was located 450 m to the east of Bahr el-Lebini' (Hawass 1997:248). Hassan refers to a thick limestone and basalt wall known as the 'Zaghloul Street Wall' (see Lehner 2009:110, pls. 8, 10, 15; also Hawass 2005: pl. III, 12). The statement should read that the wall in question is located 450 m *west* of the Libeini, as in Hassan's further quote from Hawass (1997:250, emphasis added):

> While certainly not a breakwater wall, this ancient construction could have served to delimit the Khufu harbor on the east. It should be noted that the wall is about 450 m *west* of the Libeini channel which has been thought to be a vestige of an Old Nile channel. The area between the wall and the lower temple location could have included both a harbor and a secondary Nile channel. Otherwise it could have served as a stream-discharge channel that remained filled with water longer than the general flood plain when the annual inundation receded.[30]

Hassan (2010:138) sees Hawass's (1997) information as supporting the hypotheses that the Libeini 'is the result of an eastward shift of a channel that ran parallel to the western edge of the floodplain below the Giza plateau' and he derives a rate of '3.2 m/yr for the eastern movements of the secondary channel (1.64 km over 500 years)'.

In sum, in Hassan's (2010) view, the main Nile channel moved in amplitude of 3–4 km (measuring off Google Earth) between the eastern side of the Memphis ruin mounds and the eastern desert at this latitude. The old channels and derelict streams west of the ruin mounds, between Memphis and the Saqqara Plateau, particularly the Shubramant and Libeini canals, mark, according to Hassan, a secondary Nile channel that migrated west to east, as the work of Jeffreys and the Egypt Exploration Society's Survey of Memphis has long suggested for a Nile channel during the Early Dynastic and Old Kingdom. Jeffreys (2010:193) and Hassan (2010:137) agree that the Libeini, whether a relic of a secondary Nile channel, or a relic of a main Nile channel in Early Dynastic to Old Kingdom times, was once a continuation of the Bahr Yusuf through Middle Egypt.

Weak Secondary Channel on the West?

If we must contend with a smaller, secondary channel running close below the Giza Plateau, we should look to known secondary channels, principally the Bahr Yusuf in Middle Egypt, for understanding. A major consideration for pyramid harbours is that the secondary channel had to be wide, deep and forceful enough for the pyramid builders to deliver by boat major tonnage of limestone in various shapes and sizes. For Khufu's pyramid, Tura limestone casing blocks of the bottom course weighed up to 17 tons. Khufu's builders delivered granite beams more than 5 m long and weighing 40–60 tons for roofing the King's Chamber and the Relieving Chambers. A low-energy, high-sinuosity stream would probably not have been ideal for Merer's deliveries of stone loads weighing as much as 70–80 tons (Tallet 2017:91, 159).

Hassan's (2010:137) suggestion that a secondary Nile channel 'was most probably maintained as a transport and irrigation canal' returns us to Goyon's (1971) model of the

Memphite canal. Goyon believed this western canal supplied water to harbours fronting all the valley temples of the Old and Middle Kingdom pyramids, from Hawara and El-Lahun to Saqqara, and to a great river port of Memphis, with an outlet there into the Nile. He saw the Libeini as the continuation of this Memphite Canal on its bend northwest, from Abusir to Giza and Abu Roash, so servicing valley temples of pyramids at these sites, and thence heading down into the western Delta as the canals named Mariut (Goyon 1971:150, n. 6) and Hager.

In spite of seeing the western secondary channel as a transport canal, Hassan differs with Goyon in seeing this channel not as the large-scale waterway, or former Nile course, but as a seasonal stream 'subject to disappearance periodically and left to dry out during the winter' (Hassan 2010:137). He draws on Butzer's (1976: 16-17) summary of the Bahr Yusuf, a branch that once departed from the Nile between Asyut and Manfalut, and later near Dairut. The Bahr Yusuf flows north along the far western side of the valley and turns west into the Fayum. As noted above, a main Nile channel could measure between a few to several hundreds of metres wide and 10–14 m deep. Its levees, up to 200 m wide, rise 1–2 m, and as much as 4 m above the lowest margins of the floodplain. Low water in the main channel is 5 m below the floodplain and around 7 m below the tops of the levees. In contrast, the Bahr Yusuf was a much smaller stream in recent times. Only 20–100 m wide and 4 m deep, the Bahr Yusuf always flowed close to the western margins of the floodplain.[31]

Butzer's (1976:16–17) description of the Bahr Yusuf is based on Jacotin (1826) for conditions at the end of the eighteenth century and Brown (1887) for nearly a hundred years later. According to Brown, the Bahr Yusuf

> appears originally to have been a drainage channel from Derūt to Koshesha, formed naturally during the subsistence of the annual overflow of the Nile, by the flood water finding its way from south to north along the lowest lying parts of the flooded country, which parts run along the edge of the desert at a greater or lesser distance from it, as the channel winds in its course. (Brown 1887:614)[32]

Brown relates that because the Bahr Yusuf meandered so low near the Western Desert along the base of the lateral slope of the floodplain, it was only when artificial channels were dug to connect it to the Nile – first a channel just above Dairut, later one just below Manfalut and still later a channel that connected to the artificial Ibrahamiya Canal, a large, perennial, summer canal – that the Bahr Yusuf could take on a sufficient head of water, 8 m deep during high flood, to bring water to a series of basins between the desert and the Nile's western levee (Brown 1887:614). This basin land must have risen in elevation toward the Nile, which is why the sufficient head of water was needed for this. Brown (1887:614) wrote that 'the Bahr Yusuf has thus now a connection with the Nile sufficiently far up' – he means, to the south, up the longitudinal slope – 'to ensure a supply of water to the Fayūm all the year round'.

What are the implications for pyramid harbours of a weak, secondary channel, similar to the course of the Libeini in recent times? The channel ran through the western floodplain, or right close along the desert from Dahshur to Abusir, and then farther east of the escarpment between Abusir and Abu Roash where the bedrock escarpments open up into the Delta. Along a secondary Nile channel on the west, levees lower, gentler and narrower than those flanking the main Nile channel may have presented less of an encumbrance to drawing down water into the Khentkawes basin, especially from higher on the longitudinal slope to the south. The more powerful the secondary channel, the more it would have built up its own levees.

Powerful Secondary Channel on the West?

According to Bunbury and Jeffreys (2011:71–3), the western branch was fairly stable, but became the minor of two Nile channels, diminishing to the secondary branch named 'Maaty' by Middle Kingdom, and to a very minor stream into the New Kingdom and Ptolemaic period.

Counter to the diminutive characterisation of secondary channels, like the Bahr Yusuf, by others, Alleaume (1992) stressed the force and magnitude of Egypt's lateral streams in her account of 'le réseau secondaire' in the last two centuries. Writing in general terms about pre-nineteenth-century Egyptian Nile Valley hydraulics, Alleaume (1992:304–5) stated that along the base of the lateral slope of the valley floor ran longitudinal depressions up to 4 m deep and that through these shallows ran large watercourses ('grands écoulements permanents'). For this statement she refers to Linant de Bellefonds (1872–1873:3), who described the lateral slope of the floodplain down into troughs on both sides of the valley and 'en descendant du sud vers le nord, on rencontrait de ces cours d'eau considérables pendant les crues', if not exactly the powerful rivers that Alleaume envisions.

Alleaume emphasises the size and volume of the secondary channels. She cites Mubarak (1887–1889:106) that the Sohagiya channel was as wide as 220 m in places before it was regularised into a canal with a width of about 80 m (Alleaume 1992:306, n. 15), and Barois (1904:84) that the Girgawiya Canal flowed with a volume of 29,700 cu m per second at low water and 48,400 cu m per second at high water. She compares these values for the flow volumes of the Loire during flood, 1600 cu m per second, and the Rhone, 6000 cu m per second and 10,000 cu m per second (Alleaume 1992:306, n. 16), noting the catastrophic effects when these lateral streams overflowed barrages and dykes (Alleaume 1992:305), and she cites Linant de Bellefond's (1872–1873:5) comparable observation about the Bahr Yusuf and the Koshesha dyke.[33]

Following Linant de Bellefonds, Alleaume also states that these lateral watercourses formed a nearly continuous line from the Qena promontory, through northern Upper Egypt and Middle Egypt into the sea.[34] She equates the lateral branches in Upper Egypt with the Nile branches that ran through the Delta ('dans le Delta, les anciennes "branches" du Nil sont du meme type'), but suggests that the Delta branches had greater movement and interconnections with one another over time. Before the nineteenth century, she argues (Alleaume 1992:306–7), the lateral waterways retained enough water to cultivate adjacent land, and these streams were central to their own flood regimes, with their own inundation plain, independent from the Nile during low water. However, because these courses were transformed into canals and drains (in the nineteenth century CE), we do not recognise them for what they once were, except for some traces in the landscape.

According to Alleaume, these streams and the Nile divided the valley into two parallel hydraulic zones, sometimes separated by large longitudinal dykes. Alleaume suggests that, like the Nile, these lateral streams (and here we are dealing mainly with the Bahr Yusuf in Middle Egypt) progressively deepened their beds through erosion, generated other smaller streams, and spread alluvial layers that built up 'le même profil inversé que celle du fleuve. À la limite des deux *mafrash* [inundation plains], se forment parfois de grands bas-fonds (*bâtin*), plus ou moins continuos et qui sont à leur tour utilisés pour l'irrigation' (Alleaume 1992:306–7).

As an illustration of this last point – the doubled profile of two convex, laterally sloping flood plains between two channels, the Nile and its secondary channel – Alleaume refers to a profile across the Nile Valley at the latitude of Minia that Willcocks and Craig (1913, I:93) published, where the Nile and the Bahr Yusuf created the doubly convex floodplain (Fig. 11.9). The result is not just a lateral slope to one side of the valley, or a simple convex slope when the Nile flows more toward the centre of the floodplain; rather, with two lateral floodplains, we expect double convexity, or something more complex.

Butzer (2016: 61–2) emphasises this mid-valley swale as providing a natural precursor for the system of basin chains and feeder canals of the nineteenth and early twentieth centuries, noting that 'the industrial-era system could be grafted onto an existing base with comparative ease. However, he critiques Alleaume's use of the Napoleonic maps to make the point that no such system existed before the early nineteenth century, while agreeing that the later system 'is not paradigmatic for traditional irrigation in Egypt'.

As for Giza in the earliest periods, Butzer (2016:74) sees that 'largest, suballuvial channel […] located 500-1000 m northeast of the Khufu harbor' as having 'a depth of 5 m' (compared to 10-14 m depth for the modern Nile trunk channel), 'width ~ 500 m, <u>meander wavelength ~ 2 km</u> and cross-sectional area ~1500 m^2'. He reiterates: 'This large sinuous channel qualifies as a *branch,* rather than the main Nile channel, although it is the largest such feature found in the [AMBRIC 1989] bore profiles.' Relating this specifically to the transport of stone from the eastern Tura quarries to the Giza Pyramids by boat, and referring to Willcocks and Craig (1913) for the character of the branch, he concludes that 'Old Kingdom water-borne transport to the Pyramid Valley Temples could have readily used a longitudinal canal the size of the current Bahr Yusef.'.

Floodwater for Free: A Natural Giza Catchment?

Alleaume may have overdrawn the magnitude of lateral streams, at least insofar as they existed during low-water season. While most commentators do agree that secondary waterways flowed with force during the inundation, two of Alleaume's characterisations might belie the diminutive nature of the secondary channels during low-water seasons. These are that former courses of these lateral waterways were sinuous, indicating their origin as natural streams – as previously argued by Linant de Bellefonds (1872–1873:4), Brown (1887:614) and Butzer (1976:16–17) in relation to the Bahr Yusuf – and that their intake was generally established above the level of low water in the Nile (Alleaume 1992:306). During low Nile, the secondary channels could take ground water at the lowest points in the valley floor where the water table is closest to the surface, particularly in a linear swale, a *bâten*, near the desert.[35] Again, this accords with Linant de Bellefonds, who argued that the Bahr Yusuf, while *not* receiving water from the Nile during low flow (similar to the Libeini), retained water from its own low-elevation bed (Linant 1872–1873:4) . However, it should be noted he also stated that water from ground infiltration (*on a time lag of two to three months with respect to the Nile flood wave*) could be brackish, leaving salts that effloresce when the ground water recedes (Linant 1872–1873:7). As for the continuation north of

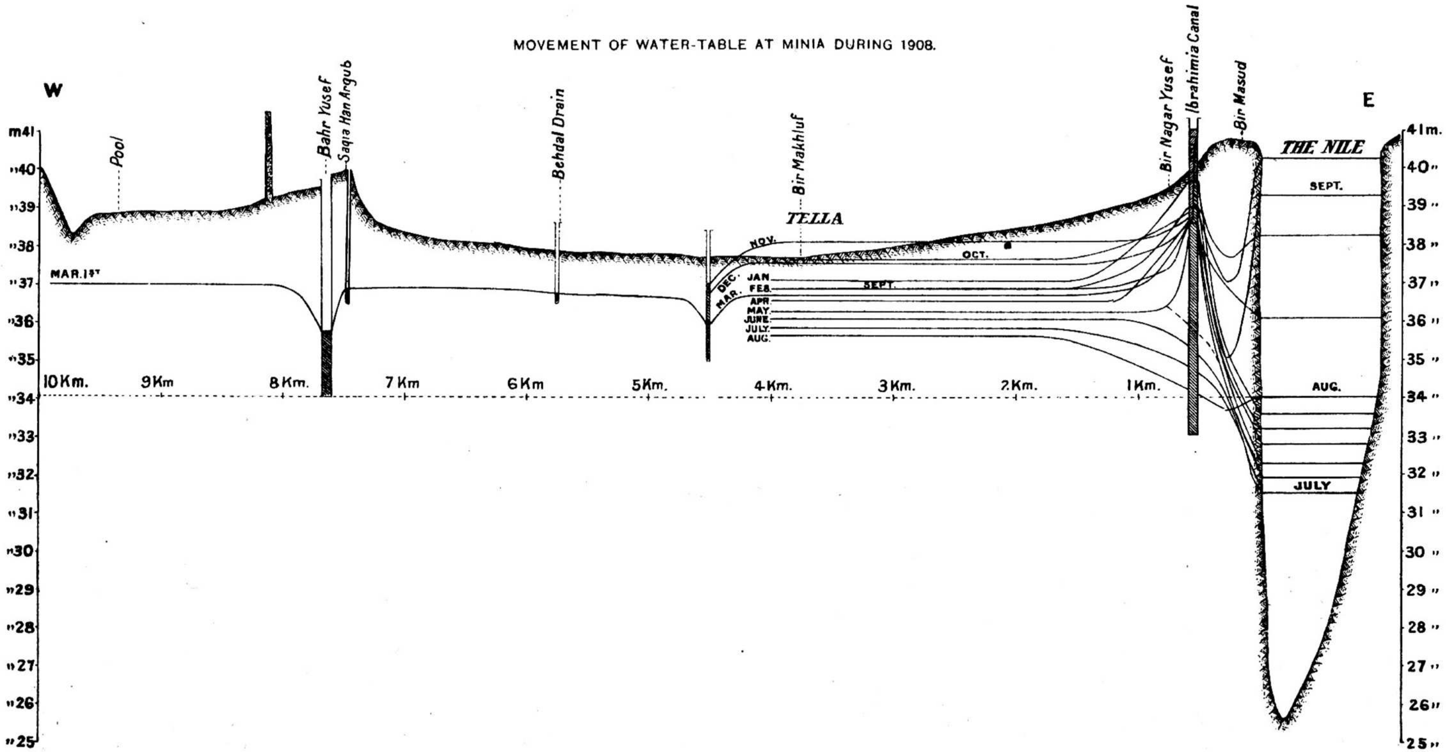

Figure 11.9 Willcocks and Craig's (1913, I:93, fig. 2) profile (with exaggerated vertical scale) across the floodplain at the latitude of Minia in Middle Egypt. The authors published the profile to illustrate the slope of the water table, but it also shows the double convex floodplains created by the Bahr Yusuf and the Nile.

the Bahr Yusuf as the Libeini, Alleaume (1992:305, n. 14) argues that 'les grandes inondations dans la plaine Memphite étaient provoquées non par le Nile, mais par le Libayni,' while stating the channel is one of the most modest of these lateral streams.

Whatever the force and magnitude of a secondary channel on the west, with the main Nile channel on the eastern side of the valley we are back to an extensive lateral slope down to the west, along the lines of the 1977 floodplain east of Giza as rendered in Fig. 11.7 above. Further, with the high levee land flanking the main Nile on the east, the entire valley floor would have dipped westward, so that the lowest floodplain near the desert edge might indeed have been close to the best estimate for the Dynasty IV floodplain, which is 12 to 12.50 m asl (Lehner 2009:142). This is close to the lowest elevation we have recorded in the bottom of the Khentkawes Town east basin, at 11.37 m asl.

To turn once again to the Bahr Yusuf, Brown noted that because it flowed near the bottom of the lateral slope, along the lowest part of the floodplain, the lands to the west of it are 'as a rule, simply flooded by the final overflow, assisted by a few cross banks to hold up the water to some extent, but these banks are merely the rudiments of degraded basins, or the embryos of basins in an undeveloped state' (Brown 1887:615, see also sketch map on page 616). If, in the early Old Kingdom a secondary channel, similar to this, flowed along the western valley from Dahshur to Abu Roash, high bank land flanking a very deep channel would not have challenged Dynasty IV builders in their landscaping and hydraulics at Giza; or, to the extent that a Dynasty IV secondary channel built up its own levees and followed even roughly the course of the Libeini, a secondary catchment zone would have existed between the channel and the Giza Plateau, along the lines of the western zone in the profile of the Bahr Yusuf and Nile in Fig. 11.9 above. The Dynasty IV builders could have simply allowed the annual inundation water to collect in this catchment zone at the bottom of the long lateral slope from the eastern Nile levees. They could draw water off the secondary stream or from this reservoir to a basin that they had excavated farther west.

The situation would have been similar to the inundation at Giza before the second Aswan High Dam, when the broad swath along the eastern base of the Giza Plateau was the first to inundate, and the last to drain, as shown in Fig. 11.10. The photograph shows the first spread of the Nile inundation water into the linear catchment between the Marioutiyah (Muhit) Canal and the low desert below the Giza Plateau. The Marioutiyah tracks close alongside and east of the Libeini, and a secondary channel here might have built up its own levees, as did the Bahr Yusuf (Fig. 11.9 above), and these may have created a reservoir that held water for longer. In the early nineteenth century CE, when the flood receded, the swath between the Libeini and the desert was slow to drain at Giza, which for local agriculture presented a problem that required augmenting the drainage of the old Libeini and more recent Marioutiyah canals. I believe the 'new channel' installed after the 1935 flood, apparently the subject of the photograph in Fig. 11.10, was the Mansouriyah Canal.[36]

It remains to be seen, however, whether a sinuous, narrow and shallow waterway can be reconciled with the image of many barges delivering heavy loads of stone and other materials, and making round trips, which necessitates two-way traffic. Also, if the bottoms of the Dynasty IV artificial basins at south Dahshur and east of Khentkawes *were* coextensive with the contemporary floodplain and nearly flush with it, they would

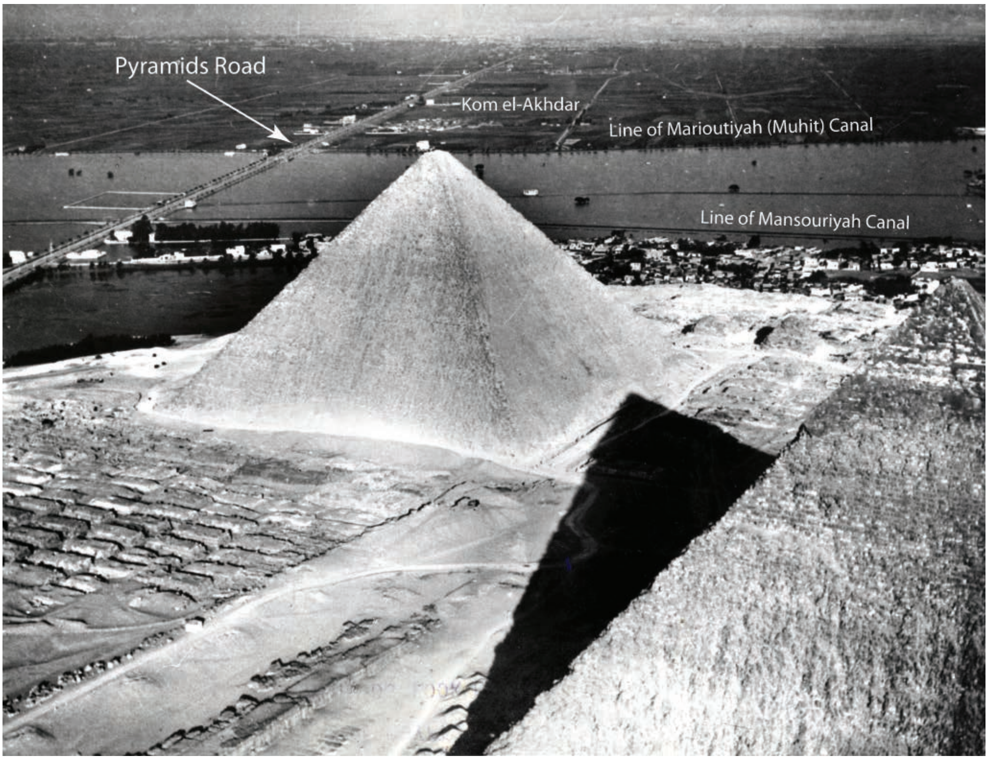

Figure 11.10 Aerial photograph looking over the northwestern corner of the Khafre Pyramid to the Khufu Pyramid and floodplain beyond, showing Nile floodwaters filling the low ground between the course of the Marioutiyah (Muhit) and Mansouriyah canal. The photo was previously part of a newspaper archive, and the label on the back reads: 'EGYPT. – An aerial photograph of the pyramids, and the river, which after the present inundation is to be defected into a system of flood control canals in a new channel. Photo from Wide World: 830527 [torn – 3?], courtesy Ministry of Aviation of Egypt, Egypt [torn – Royal?] Air Force. D–8/12/35' [12 August 1935]. Given the mid-August date, the photo shows the spread and swelling of floodwater at the beginning of the inundation season (image purchased by author via a private seller on the internet).

have received water only to a depth of 1.5 m on average, if the flood behaved as it did during the nineteenth and early twentieth centuries, when its depth over the fields varied from 1–3 m deep and averaged 1.5 m (Willcocks 1889:44; Willcocks and Craig 1913, I:305). This may be too shallow for those uses that would qualify the basins as harbours (Butzer 1976:17, 45). On the other hand, these basins could be deeper toward their centres, and draughts are not a major factor. In recent centuries, the largest Nile boats could carry up to 185 ton with draughts of only 2.20 m (Willcocks and Craig 1913, II:594, table 235; cf. Cooper 2014:12, table 7.2, cited by Tallet 2017:90, 157–8 for estimation of Merer's boats).

The key variables here for a western channel are the force, width and depth of water during flood season. When we see in recent centuries that cargo shipping was reduced to the flood season (Cooper 2014), perhaps a secondary channel and a floodplain similar to that of 1977 could have met the needs, while requiring less intervention and less labour and cost to modify. I therefore reiterate Butzer's (2016:74) conclusion that a channel the size of the recent Bahr Yusuf could have allowed transport of stone to the Giza pyramids. A meander wavelength of about 2 km would allow an approach to Giza along four or five bends, with a final curve to Giza starting just north of Zawiyet el-Aryan.

Two or More Major Channels? Head of the Delta South of Giza

A number of researchers who for some years have focused on river movement in Egypt's capital zone have inferred that in early Egypt the 'apex' or 'head' of the Delta lay farther south than Giza. If the Nile trunk channel split south of Giza into large branches like the Rosetta and Damietta of today, that would have left two or more streams of some magnitude east of the Giza Plateau. This may be the most compelling of the possibilities, resulting in a compromise on the scale of a western Nile channel we choose to model at Giza.

Michael Jones (1995; 1997) has concluded that evidence of borings in Abu Roash, Ausim and Doqqi, more or less on the central axis of the Delta apex, indicate an eastward migrating floodplain, changing water courses, and a Delta apex in the first millennium CE 20 km south of its present position:

> The west bank landscape of settlements on levees, or on already developed archaeological hills (kom or tell), with water courses beside them suggests that the apex of the Nile delta was situated considerably further south than its present position as recently as the mid-first millennium AD. […] In the late Roman and early Arab periods the Nile was dividing into its delta branches somewhere in the central or southern part of modern Cairo, probably in the vicinity of Roda and Babylon, with a major western branch flowing through modern Doqqi and el-Muhandisin. (Jones 1997:111)

For some time, David Jeffreys has explored the hypothesis of a more southerly Delta head, with the split of the river into two (or more?) distributaries as far south as the latitude of North Saqqara. Lutley and Bunbury (2008:4) suggest 'that the Delta head was further south in the past' with 'a high flow rate' and 'more numerous distributaries'. As for Giza, though, they state that '[a]t what point there ceased to be more than one branch of the Nile at this latitude (one of the others passing by Heliopolis) has yet to be determined' (Lutley and Bunbury 2008:4). Jeffreys (2008:6) cites their observations as support 'for the idea of the Nile Delta head having moved over 30 km from south to north in the last 5,000 years, in addition to the general eastward trend in the course of the river itself in this exceptionally narrow stretch of valley'. If we take the modern 'Delta head' as the island el-Warraq, west of Shubra el-Balad (MHR Sheet I–12), 30 km south puts us opposite South Saqqara and just south of the Memphis ruin mounds. If we take the current Delta head as the actual split of the Rosetta and Damietta branches north of the island el-Qiratine (MHR Sheet F-9), 30 km south puts us just north of the Abusir embayment.

Jeffreys builds on the hypothesis of a more southerly Delta head the additional hypothesis that the migration of the Nile bifurcation northwards helps explain the migration of 'capital' settlements from the Early Dynastic 'White Walls' to Memphis at Mit Rahina, Old Cairo and Fustat, and the eventual formation of the Fatimid city and modern Cairo. In his hypothesising here, Jeffreys had already invoked the Predynastic sites at Maadi, Omari, Tura and Helwan (see Jeffreys and Tavares 1994:164, fig. 4), which observation F.A. Hassan (2010:6) repeated in connection with his hypothesis of an early main channel on the east (see above). Jeffreys also postulates an early eastern branch near Memphis, but not quite as far south as Memphis:

> Also important for us is a projection back in time to the earliest occupation: the 'pre-Memphis' settlement sites such as Maadi and Omari on the east side, perhaps all benefiting from branches of the Delta network that flowed closer to the east bank in the fourth millennium as well as from more active *wadi* systems, and the cemetery sites that succeeded them in the Early Dynastic Period (Helwan/Maasara, Tura, Batn el-Baqara/Fustat). Significantly, the most intensively used cemetery areas, Saqqara and Helwan, lie across from one another at the narrowest point of the valley at or just above the projected contemporary Delta head. (Jeffreys 2008:7)

Further (Jeffreys 2008:7), 'the Delta proper began at the latitude of Abusir in the early to mid-third millennium BC', and 'after the end of the Third Dynasty the desert edge on the east side seems to have become less popular as a place of burial: Were habitation sites east of the river already threatened by changes in its course?' Such changes would have entailed, in Jeffreys's model, the movement of the river split to the north; or in F.A. Hassan's view, the migration of the eastern channel toward the west.

As of this writing, Bunbury and Jeffreys (2011) have made the latest contribution to the question of the migrating 'Delta head' or 'Delta apex'. They now consider that the 'division of the Delta' could have been as far south as the entrance to the Fayum, based on the track of the Libeini:

> The precise location of the most southerly displacement of the head of the delta remains to be determined but we can assume that, with time, it has been broadly migrating northwards to its current position. Recent unpublished work by David Duffton (pers. comm.) suggests that the Bahr Libeini can be traced as far as Maidum and the entrance to the Fayum and this may reflect the division of the delta at this point at an earlier time. (Bunbury and Jeffreys 2011:66)

Delta Head and Hard Rock Geology

When are two channels a 'delta head', and when are they just two channels? Can we speak of a 'delta head' within a valley narrowed to 6 km by the hard, geological constraints of the high desert?[37] Secondary Nile channels split off in Middle Egypt as the Sohagiya and Bahr Yusuf, but could we call those bifurcations a 'delta head'? The 'head of the delta' can hardly be defined only as a split into two channels.

The Nile Delta is the namesake of river deltas, alluvial fans that build up and out into standing bodies of water (Bridge 2003:301). By definition, the delta *shape* begins when the river begins to expand its width beyond its channel. With expanding flow and reduced slope, velocity decreases and diminishes the ability of the river and distributaries to carry sediment, so they must drop it. Deltas and fans are a function of the river moving out of its hard constraints, its 'geological controls' (Bridge 2003:296), or what Stanley (2005:4) calls 'accommodation space, the depressed/lowered land surface upon which sediments accumulate'.

We take as the 'head of the Delta' the point at which the river expands its flow and its floodplain begins to fan out, although the point at which the river channels split is what most informs water transport infrastructure at Giza. According to Jeffreys and Tavares (1994:158), the Wadi Hof and Wadi Digla fans constricted the valley to 3 km at the latitude of Memphis and Saqqara in Early Dynastic times, with its much lower floodplain. We can hardly think of a 'delta head' in this corridor, as narrow as it is from here down to the Fayum entrance. Jeffreys, as quoted above, suggested that in the early to mid-third millennium BCE the 'Delta proper' began at the latitude of Abusir, and this this where the narrow corridor of the 'capital zone' begins to open, north of the North Saqqara escarpment and the village of Abusir (Fig. 11.11). Just here, the western escarpment forms the southwestern corner of a great jog or bend of the Nile, its valley and the course of the Libeini Canal toward the northwest. Across the valley, the Moqattam Hill forms the northeastern corner of the jog and the opening of the eastern Delta. The river then swings back north at the island of Gezira, just south of the island of Roda, opposite Maadi and Old Cairo. It seems the river bent to go round Gebel Moqattam and its lower terraces east of Tura (Jeffreys and Tavares 1994:159), an impression more strongly conveyed in the stitched-together sheets 21 and 24 of the Napoleonic *Atlas géographique*, and also noted by Peter Sheehan (2010:25–6, n. 18) for bedrock terraces at Old Cairo.[38]

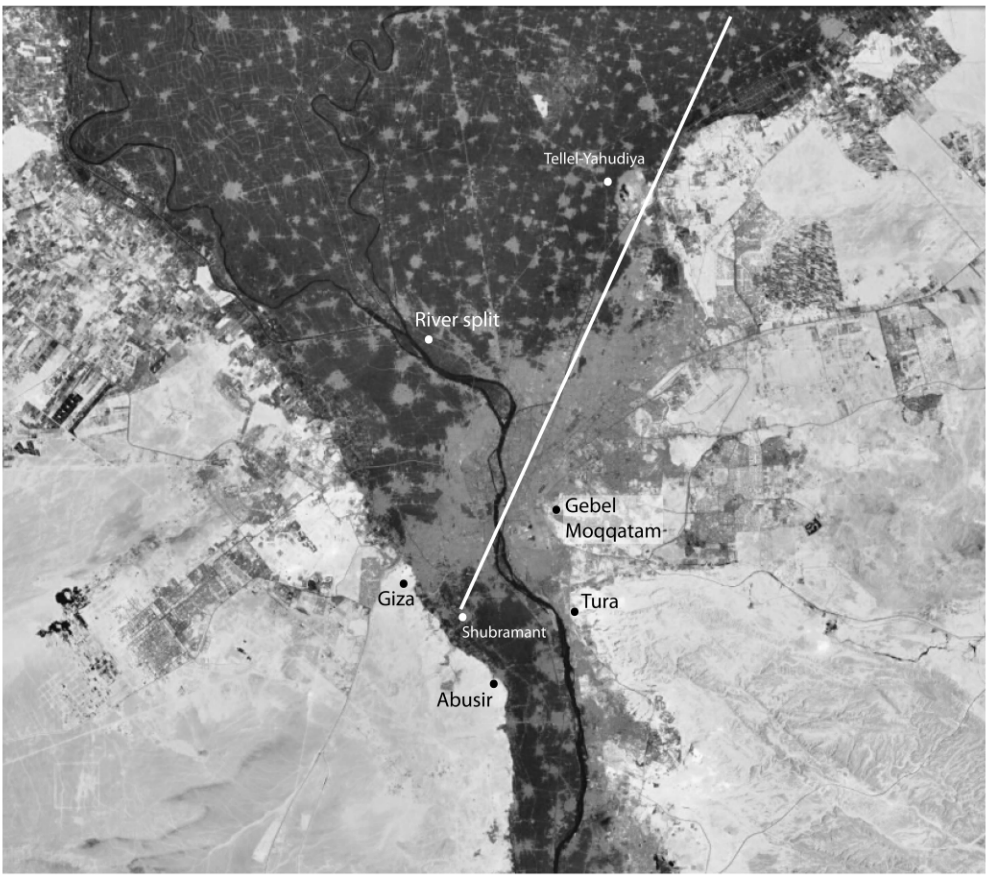

Figure 11.11 Northern Nile Valley and Delta apex. The line from the edge of the bedrock outcrops at Tell Yahudiya and Gebel Moqattam roughly corresponds to the course of the waterway formerly known as Trajan's Canal. The line ends at the lower southeast (left), approximately at the course of the Bahr el-Libeini near Shubramant (image from Google Earth).

By early historical times, any trunk Nile channel would have cleared Gebel Moqattam at a point just north of Abusir (Fig. 11.11). Here an alignment was then possible with the northeast–southwest-running eastern edge of the Delta desert border, and just along this border ran the waterway Amnis Traianis, which might track the course of the easternmost of ancient Nile distributaries. This waterway, and the alignment to the intersection with the hypothetical Third Millennium western (trunk) channel, also needed to clear the bedrock outcrop at Tell Yahudiya, northeast of Moqattam. This line runs just south of the modern Pyramids Road across the Giza Plain, and intersects the Libeini and Marioutiyah canals at about the location of the town of Shubramant, 6 km southeast of the Dynasty IV Heit el-Ghurab settlement site at Giza. This is, basically, what Jeffreys and Tavares (1994:159, 173, fig. 15) concluded by projecting the line of the eastern waterway corresponding to Trajan's Canal to where it meets their hypothesised course of the main Nile channel along the line of the Libeini. This puts a bifurcation of the main channel only slightly south of Giza (at UTM N3315), but not as far south as Memphis-Saqqara.

Memphis-Abusir River Split and Transit Hub

A Delta head at Abusir in Dynasty IV would have seen the bifurcation of the parent Nile channel only 6 km south of Heit el-Ghurab at Giza, near Shubramant. Today the valley is only 8–9 km wide here, as opposed to 36 km wide where the Rosetta and Damietta split slightly toward the western side of the Delta apex. If the trunk channel split more to the western side of the Delta apex in the Old Kingdom, the eastern branch (assuming for the moment only two),[39] would have to cut diagonally across the floodplain, along the lines Jeffreys and Tavares (1994:173, fig. 15) mapped for 3700 BCE. In this case the eastern branch practically misses Maadi, and if Maadi, El-Omari and Helwan owe their location, in part, to an eastern Nile branch, while a western branch ran close to Saqqara and Abusir, the split into two channels would almost have to be south of Memphis, especially if the split was long and lenticular, like that of the Rosetta and Damietta (Fig. 11.11 above).

Two large channels, albeit somewhat smaller than the trunk channel – one on the east and another on the west – would render a different flood plain than that of 1977 (Fig. 11.7 above), or what we obtain by simply flipping its profile from east to west (Fig. 11.8 above). We should expect a floodplain of double convexity along the lines of the profile across the Bahr Yusuf and Nile floodplains at Minia (Willcocks and Craig 1913, I:93, fig. 2 = Fig. 11.9 above).

For insight into an ancient Delta head just south of Giza we might look to the features of the Rosetta and Damietta branches, just downstream of the modern Delta head, with all due consideration of the much broader accommodation given by the hard geology and the modern barrages at the contemporary split. As mapped by the French in the *Atlas géographique* (Jacotin 1826: pls. 2–25) prior to extensive engineering, this bifurcation occurs where the floodplain is now about 34 m wide at a point 21 km northwest (about 16 km due north) of the bedrock gate, 16.5 km wide, established by the Abu Roash and Moqattam outcrops. The parent channel first turned markedly *west* about 11 km north of Gebel Moqattam at the island of Waraq el-Hadar (which still exists), and only then does the Damietta strike a north-northeast course toward the western side of the Manzala Lagoon.

The mean width of the Rosetta was 500 m, in contrast to the 270 m mean width of the Damietta (Willcocks and Craig 1913, I:296). It should be noted that the Rosetta width equals Butzer's (2016:74) estimate for the width of his inferred early Holocene, suballuvial channel at Giza. The Rosetta flows at a lower elevation than the Damietta, the banks of which were perched 1.30 m higher in absolute elevation where the two channels were 50 km apart (Barois 1889:13); this was probably because the Damietta once carried more sediment, creating the overall convexity common to fans (Bridge 2003:302). For the first stretch downstream of the apex, the Rosetta flowed steeper and would scour its channel, while the Damietta tended to silt up. The Rosetta rose less above the adjacent country, and carried most of the water from the parent channel, about 70% (Said 1993:70).[40] Several streams that departed from the Damietta delivered up to one-third of its waters to the Rosetta (Willcocks 1903:50–4; Said 1981:81).

This higher elevation of flow of the Damietta accords with a relationship we see through Middle Egypt between the higher parent channel on the east, and the low-lying Bahr Yusuf on the west – albeit in the Delta in recent times the lower, western Rosetta channel carried the greatest volume. If, in the early Old Kingdom, a western river flowed at a lower elevation and with greater force, it too could have drawn water from the east. These are variables that see great change. Alternatively, however, a Delta head south of Giza in the third millennium BCE could have made for more than two channels in the floodplain east of the Giza Plateau.[41] After the split, branches need not have been unified, continuous waterways (see Cooper 2014:76 for the Damietta). Anastomosing channels (channels that actively re-join downstream) may have formed a series of large islands, different branches or distributary channels (if the divided channels do not re-join), and ancient textual references to channels west and east of Memphis and to the 'Islands of Memphis' (Jeffreys 1985:52–3) could reflect synchronic settlement patterns of greater Memphis (Jeffreys 2010:193) within a series of such channels.[42]

Immediately upstream of the Delta head of recent times, the trunk Nile channel broke into large islands and then bifurcated as it swung left across the widening floodplain. The most northern of these islands, Geziret Chalaqan (or Shalakan, named after a village on the east bank), was triangular, with its northern side defined by a cross channel, called *Baten el-Baqarah,* or *Ventre de la Vache* ('Belly of the Cow'), between the Rosetta and Damietta branches.[43]

As mapped by Napoleon's Egyptian Expedition before the barrages were built, these islands become progressively smaller upstream of Geziret Shalakan, with thinner wedge-shaped islands flanking the larger ones on the north. Using the scale on the *Atlas géographique* (pls. 24–5), I measured the dimensions of the larger, main islands as shown in Table 11.1.

In considering the idea that the 'Islands of Memphis' may have included actual islands (Jeffreys 1996) immediately above the head of the Delta at Abusir (Jeffreys 2008), we could compare the dimensions of the modern islands to the ten ruin mounds of Memphis (*tells* or *koms*) with intervening pools (Jeffreys 2001:373). Altogether, the ruin mounds of Memphis extend 4.5 km north to south.[44]

Island	Length km N–S	Width km E–W
Shalakan	3.3	1.69
Abu el-Gert	6.01	1.72
Waraq	4.88	1.42
	5.12	1.70*
Boulaq	3.46	1.15
Roda	3.37	0.53

*1977 MHR map sheet.

Table 11.1 Dimensions of islands in the Nile.

Braiding or anastomosing channels (Bridge 2003:149) in the in the area north of Memphis would have presented both challenges and opportunities for Merer and his men to cross from Tura to Giza. They apparently approached Giza from two different itineraries, depending on whether they left from Tura North or Tura South (see below). When they reached Giza from the south, they must have sailed upstream on the eastern channel(s) for a first short leg of the trip, then crossed the valley via subsidiary channels, finally moving downstream on the western channel(s), perhaps along the course of the Libeini , as Tallet (2016) suggested in a preliminary article on the toponymy of Merer's journal. By the time Merer was keeping his surviving journal, they had worked the trip into a routine.

In the same article, Tallet suggested that the *Š-Ḫwfw* and *R-š Ḫwfw*, as alternative names for the same place and institution, lay in the vicinity of Abusir, where we project the major river split in Merer's time. Merer's journal attests to both terms as bodies of water and to the *r-š* as a place of administration and delivery for the royal works. Here, Merer and his men regularly spent the night with a heavily loaded boat. Initially, Tallet located the *R-š Ḫwfw* at Shubramant, or a little south of there – the area immediately north of Abusir.[45] Here, a large lake or basin, or the bifurcation of the Nile trunk channel, could have fed into a *r-š* for Neferirkare, Sahure and Ikauhor, because a *r-š* is attested for each in Dynasty V. But it would be difficult to see these as the same installation changing names under different kings, because the Abusir Papyri attest a contemporaneous *r-š* for Khufu and Neferirkare each during the mid-Dynasty V period of the Abusir Papyri (Posener-Kriéger 1976, I:304–10). However, as Tallet suggested, a large catchment, lake or the bifurcation of the Nile trunk channel in the general area of Abusir to Shubramant could have served as a hub from points south, east and north, a veritable '"plaque tournante" sur la rive' (Tallet 2016:13) whence waterways debouched to basins dredged and built in front of pyramid complexes. To the extent that it could, the Old Kingdom Egyptian state may have engineered this strategic zone at the 'head of the Delta' (Tallet 2017:70), just as the modern Egyptian state engineered and transformed the bifurcation of the Rosetta and Damietta in the nineteenth and twentieth centuries CE.

Because Merer's journal records a day to navigate from *R-š Ḫwfw* to the pyramid *3ḫt Ḫwfw*, Tallet believed the former should be some distance from Giza, to allow for this travel time. In his presentation and analysis of the complete set of fragments of Merer's journal, Tallet (2017:35, n. 58) sees the two terms as referring to distinct places, or to distinct parts of a place, and he concludes that if Merer's arrival day included unloading the blocks, these named places could have been much closer to the pyramid. Citing Bunbury and Jeffreys (2011), Tallet (2017:70–1, n. 15) invokes the hypothesis of a Nile split below the Saqqara necropolis and suggests that a western branch along the route of the Libeini served as the downstream entry into Giza.

The Libeini and the Lead-In to Giza

Nearly all commentators agree – and it is an old idea – that the Libeini survives as a relic of an old, western Nile channel, of one order of magnitude or another.[46] We take the Libeini as a major example where modern surface contours show vestiges of ancient features.[47] Tallet points to the Libeini as possibly marking the western Nile branch, and possibly one of the two routes that Merer and his men took to Giza. While nothing in the Wadi el-Jarf Papyri confirms this, Merer's northerly course after crossing from Tura had to be close to that of the Libeini (Tallet 2017:70–1, 105).

In going with this inference for my most recent modelling of water transport infrastructure at Giza, I have to acknowledge again Butzer's (2016:74) contrary observation that the builders of the Giza pyramids could have used 'a longitudinal channel the size of the current Bahr Yusef' and that such a feature is 'verified in unit MH-2', but that 'this is not on the axis of the atrophied Bahr el-Libeini Canal, which did not yet follow its historical course.' Butzer comes to this observation from his reconstruction of an artificially 'overdeepened Nilotic channel (bed at 3-5 m asl)' as flowing tight against the Khufu Valley Temple, so some 900 m west of the Libeini (see Butzer 2016: fig. 5 = Butzer *et al.* 2013:3345 fig. 2C). Butzer is missing principally the benchmarks and borders furnished by Dynasty IV stone architecture exposed through excavation, such as the Zaghloul Street Wall, as well as settlement indicated through the AMBRIC (1989) borehole logs. When we take these important benchmarks into consideration, we see that in Dynasty IV the river channel must run east of the Zaghloul Street Wall, which puts us back on the course of the Libeini, which Butzer also saw as an 'overdeepened channel (bed at 4 m asl).'

The 1 m contours of the 1977 floodplain as captured in the MHR 1:5000 map series show the Libeini running through a linear depression. Below the Saqqara Plateau, the lowest floodplain contours run along two salient south-to-north channels, one along the course of the Shubramant Canal, the other along the Libeini (Lehner 2009:109–10, pls. 12–14). The low elevation channel along the Libeini is the most pronounced (Lehner 2009: pl 12); the two channels come together at the Abusir bend toward the northwest, and from that point the single Libeini channel runs northwest (Lehner 2009: pl. 13) until Zawiyet el-Aryan.

Here, the Libeini sinks 1–2 m deeper as the contours break up into four or five channels that define 'island patches' (Fig. 11.12). These multiple braided channels stretch 4.6 km to the northwest (Lehner 2009: pls. 14). To the extent that the Libeini tracks an ancient Nile course, do these contours reflect its braiding or anastomosis?

Butzer (2016:62) suggests the possibility that catastrophic nineteenth-century CE flooding furrowed these multiple channels after the failure of an old dyke detectable in the contours of the 1:5000 MHR map which ran from the town of Shubramant to

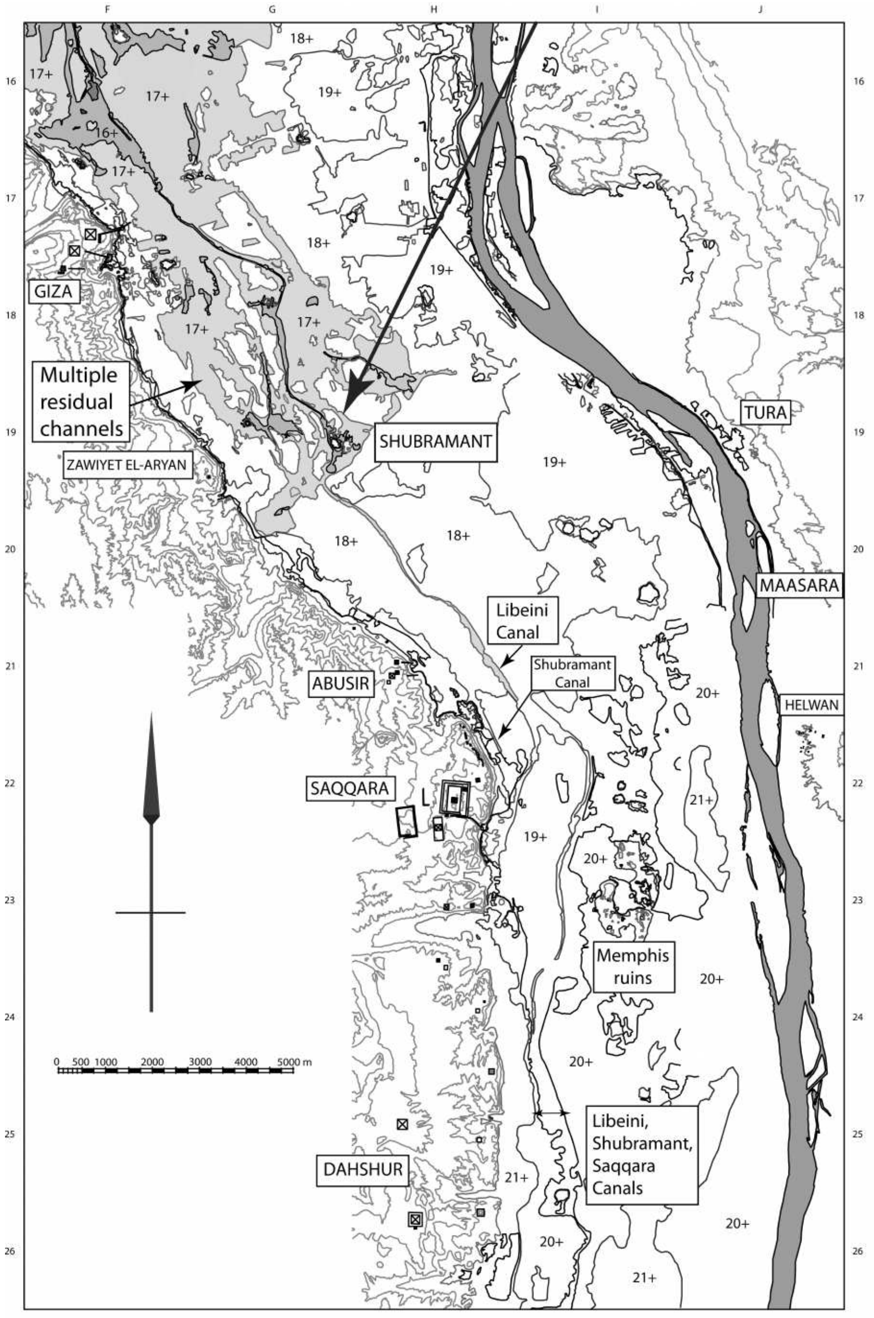

Figure 11.12 Nile Valley contours between Dahshur and Giza, with the 1977 Nile course in dark grey, and land below 18 m asl in light grey, extracted from the 1977 MHR map series, with contours of modern features (canals, roads, embankments) pinched off. The black diagonal line is drawn from Tell Yehudiya and Gebel Moqattam to the course of the Libeini, residual of an old western Nile channel, where the contour lines separate to suggest braided channels starting at Shubramant, the suggested location for the head of the Delta in the Old Kingdom.

the village Abu el-Namrus to the northwest, the bank possibly corresponding to the road named Mahager Bani Yusuf on the west and Gamal Abd el-Nasser on the east. However, these furrows may be older: the multiple linear low channels, reflected in the 1977 contours, occur just north of where the floodplain gradient increased on the west of the valley after a fairly level stretch between Dahshur and Abusir (Lehner 2009: pl. 6). This may relate to a knickpoint (i.e. a sharp change in the slope) where the Nile canyon opened to the broad Delta. This is just where we project the possible head of the Delta on the basis of the line that clears Gebel Moqattam and intersects this course (see above; also Jeffreys and Tavares 1994:159, 173, fig. 15).

Just above Giza, due east of the Heit el-Ghurab Dynasty IV settlement site, the contour lines come together again as a single, linear, low channel tracking the Libeini Canal on its southeast to northwest course passed Giza, within a broader catchment (Figs. 11.12–13) that the annual flood filled sooner and that retained water longer (Fig. 11.10 above).

It was at this point, where the braided contours come together, that I started my latest heuristic exercise[48] of modelling Dynasty IV water transport infrastructure

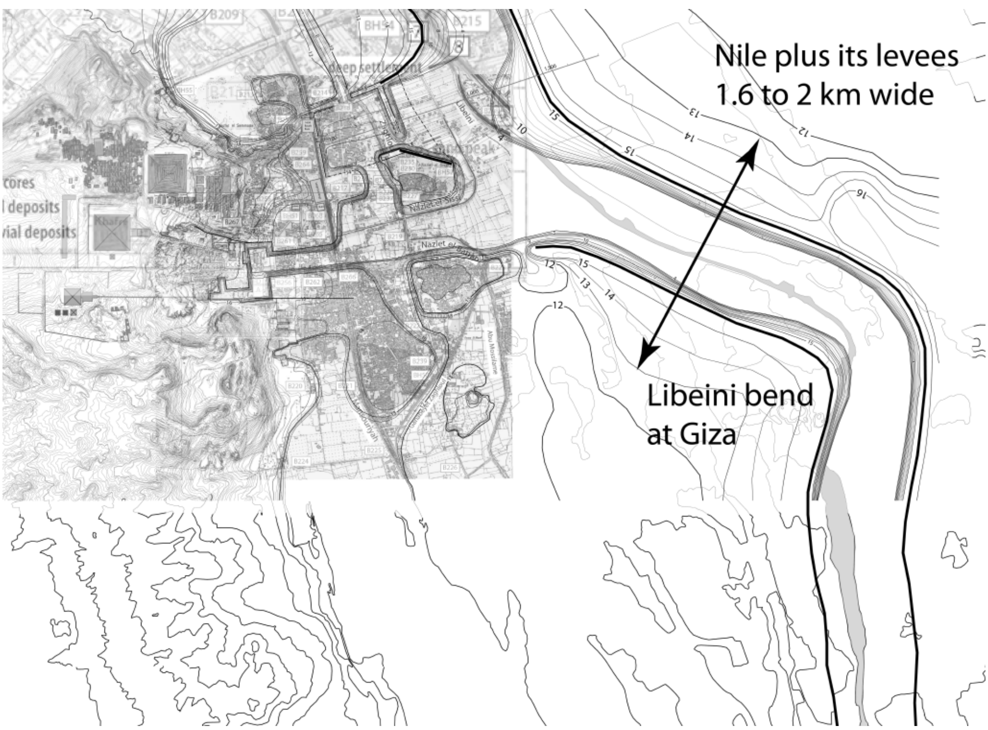

Figure 11.13 Reconstructing a Nile channel at Giza, on the scale of the Rosetta and along the track of the Libeini (greyscale). This choice was the beginning of one modelling run of water transport infrastructure at Giza, and it takes into account large features on a regional scale, principally the Libeini as a possible relic Nile channel, and then incorporates detailed information and benchmarks that have come to light in the last 30 years and that are represented on larger scale maps, here overlaid, of the floodplain and desert interface below the Giza Plateau.

at Giza (Figs. 11.1 above and 11.13) by placing a broad Nile channel, with elevation values reflecting a lower overall floodplain, along the modern course of the Libeini and its wider trough on the bend of this course further northwest as it approaches Giza. A Nile channel that followed this pronounced bend of the Libeini, just opposite the Heit el-Ghurab site, would have delivered water almost directly west, and even slightly southwest (Fig. 11.13), into the lowest access to the Giza Plateau – the area east of the Sphinx and north of the Wall of the Crow – after rounding the Heit el-Ghurab site, which extended pier-like for hundreds of metres east of the Wall of the Crow, as we know from archaeology (Lehner 2002:66–7; 2016:116–17).

Part III: Modelling Water Transport Infrastructure at Giza

In construing a model of water transport infrastructure at Giza, I took clues from four major sources: (1) modern surface contours as vestiges of ancient features; (2) ancient features encountered through excavation; (3) deep drilling that retrieved and logged sediments; and (4) geomorphology of the Nile, its levees and its floodplain in recent times. I then followed certain 'rules' of inference when using the AMBRIC boring logs and the logs of a few other deep core drillings. First, I ignored most everything above 16 m asl, because I assumed these deposits were laid down after the Old Kingdom (cf. Butzer 2016:74). I based this decision, in part, on excavated sections through the higher deposits for the foundations of modern buildings. I have seen, noted and photographed such excavations just east of the Abu Taleb Bridge, north of the road to Nazlet el-Sissi, and the excavation that exposed the Zaghloul Street Wall. Second, I took very deep, consistent, silt and clay in the AMBRIC logs as fill of ancient waterways and basins. I contoured the bottoms of basins and waterways on the basis of the elevations of the bottom of the clay/silt over starkly contrasting basal sand and gravel. Third, I assumed that Dynasty IV structures exposed by excavation delimited any deep basins and waterways, and for the most part, the river channel; that is, Dynasty IV basins and waterways did not cover Dynasty IV architecture. Fourth, with some few exceptions, I did not place deep basins, waterways or the river channel where the AMBRIC logs or excavations exposed pottery and other cultural material, which I take as settlement, at elevations below 16 m asl.

Bathymetry of a Western Nile Channel

When El-Sanussi and Jones (1997:249–51) and Butzer *et al.* (2013: figs. 2B–C, 3D, 3348) correlated AMBRIC logs,[49] they understood very deep clay and silt (the basis for my second rule of inference above) as evidence of ancient watercourses in the fourth or third millennium BCE.[50] Both publications make a valuable contribution to understanding the complete set of AMBRIC logs east of the Giza Plateau. Butzer *et al.* (2013:3344–7, figs. 2B–4) deal with the complete set of AMBRIC logs, and as previously mentioned, these authors see a Pleistocene/Early Holocene Nile branch with a meander wavelength of ~ 2 km just west of the course of the Libeini. They give a depth of 5–7 m and a 'cross-sectional area of ~3000 m^2 if fully functional at one time, compared with 7800 m^2 for the modern Nile' (Butzer *et al.* 2013:3344, fig. 2B).

In his later work on this channel, Butzer (2016: 74) gives a depth of 5 m, a cross-sectional area of 1500 sq m, and a width of 500 m, which, he suggests 'would have carried no more than 20% of the modern Nile volume and medium flood stage'. He sees the extraordinarily deep clay and silt in the AMBRIC cores, down to 4 m asl or deeper, as evidence of 'overdeepened channels'. Butzer *et al.* (2013:3348) see this hypothetical channel as originating through natural causes, including wadi activity, but also, along with fault-like discontinuities, due to humans dredging harbours for the Khafre and Khufu pyramids – hence their reference to 'the Khufu Harbor channel'.[51] The authors imply that the Dynasty IV Egyptians engineered this secondary, western Nile branch channel, or its successor. They plot a curvaceous 'Old Kingdom Nilotic channel' that flowed right in front of the Khufu Valley Temple (their fig. 2C).

However, these authors are missing Dynasty IV structures and settlement exposed through excavation and evidence of settlement in the AMBRIC logs. These finds augment the evidence of the AMBRIC cores and serve as *benchmarks and boundaries* for the Dynasty IV engineered land- and riverscape. Many of the AMBRIC logs show consistent, relatively uninterrupted, deep clay and silt below 15 m asl down to an elevation around 7 m asl (Fig. 11.14 below). Some show *very deep clay and silt* down to an elevation of 3 m asl and lower. Borings penetrated the very deep clay and silt east of the location of the Khufu Valley Temple, as well as between that temple and the Zaghloul Street Wall, all around the 'island' of Nazlet el-Sissi and between Nazlet el-Sissi and Nazlet el-Batran East (which I construe as 'gateway settlements' – Lehner 2014b:19–20).[52]

The deep clays and silts 'bottom out' on sand and gravel devoid of clay and silt. El-Sanussi and Jones (1997:250) remark on this stark contrast, as low as 3 m asl. They see the basal sand and gravel as 'fluvial sandbars […] covered by Nile sediments over a period of many centuries'. Butzer *et al.* (2013:3344) recognise the basal sands and gravelly sands as Late Pleistocene fill 'disconformably overlain by nilotic muds'. Butzer (2016:72) further notes that the deep, basal clay and silt rests 'on compact Pleistocene sands', marking a 'radical shift from an unstable braidplain to a low-energy, convex floodplain'. The deepest clay and silt fill the cut of Butzer's (2016:74) 'largest suballuvial channel trace' which was 'entrenched into the Late Pleistocene braidplain.

More prosaically, the Nile and its branches would not deposit most of its clay and silt within its active channel; it spread this fine material over the floodplain to either side during its inundations. But once the channel moved by cutting a new course farther east, the old trough would choke and fill, not just with clay and silt from the annual flood, but also with sand and gravel washed from the wadis and aeolian sand. East of the western wadi mouths, we would expect core drillings to show a 'normal profile' of silt and clay from Nile inundations interleaved with sand and gravels that washed out of the desert by wadi flooding. But farther away from the wadi openings, I expect the Nile floods would have gradually filled old channels and natural or artificial basins more solidly with deep silt and clay.

Broad wadis frame the Giza Plateau north and south (Fig. 11.2 above). In between these two wadis, the central wadi separates the Moqattam Formation outcrop (the pyramid plateau proper) from the southern Maadi Formation outcrop. The Dynasty IV builders quarried the bottom and sides of this central wadi more than 30 m deep,

Figure 11.14 AMBRIC borehole locations superposed on the 1977 MHR 1:5000 maps of the Giza Plateau and floodplain. Rectangles label AMBRIC core drillings coded for types of deposits below 16 m asl. Boring logs in areas shaded dark grey (roughly corresponding to modern settlement as of 1977) showed settlement (pottery) over continuous, deep, sand and gravel (B256, B262 and B222), or over layers of deep clay (*ca.* 7 m asl), often thin layers (e.g. B268, B265, B261, B263, B266, B239 and B221). Boring logs in areas of medium-shade grey, e.g. between Nazlet el-Sissi and Nazlet el-Batran (B214, B236, B238, B237 and B219), show very deep clay and silt, down to 3–4 m asl. Borings in lightly shaded areas (e.g. B218, B224, B225 and B226) show deep clay, generally bottoming out on sand/gravel around 7 m asl (adapted from original map with colour codes).

and we should expect that east of this wadi they also excavated deeply into the natural depositional sequence of the flood plain to create a harbour and delivery basin. After the pyramid builders abandoned their deep interventions into the floodplain – their excavated basins and canals – annual Nile inundations would have filled them with 'overlydeep' (Butzer *et al.* 2013) silt and clay.

For my current attempt to model Dynasty IV water transport infrastructure at Giza, I chose to reconstruct a Nile channel 500 m wide, the mean width and depth of the Rosetta (Willcocks 1889: pl. VIII; Willcocks and Craig 1913, I:296–8), and the width Butzer (2016:74) gives for his beginning Holocene channel (Figs 11.13 above and 11.15 below). I based its depth, in part, on reports published in the nineteenth century that the Nile channel ranged from 10 to 14 m deep, but I also modelled the depth on the basal contact between the deepest clay and silt upon the Pleistocene sands as given in the AMBRIC (1989) borehole logs. That is, I take the bottom of the clay/silt over sand/gravel as the bottom of this Nile channel, and contour it accordingly, to develop a paleo-bathymetric model.

The assumption that the basal contact between clay/silt and sand represents bathymetric bottom of the former Nile branch and of Dynasty IV waterways and basins should certainly be questioned critically, because the AMBRIC logs along the latitudes of the Giza Plateau and beyond show two levels of contact between upper clay and silt built up over sand and gravel. Certain AMBRIC borehole logs show a distinct clay over sand contact near 4 m asl, while other AMBRIC boreholes show a higher sand/clay contact close to 7 m asl (see below).[53] I would understand the contact between upper clay and silt around 7 m asl as the 'normal' beginning of Nile clay and silt alluviation over a Pleistocene sand and gravel bed. I interpret the 'overlydeep' contact between clay/silt and sand/gravel near 4 m asl as natural river cuts (channels) or human interventions.

For the sake of modelling that tries for coherence between the borehole logs, subtle surface contours as vestigial of ancient floodplain relief and Dynasty IV architecture as revealed by excavation, I assumed a Dynasty IV floodplain around 12–12.5 m asl based on evidence (summarised by Lehner 2009:142). To reiterate, I assumed that the clay/sand contact near 7 m asl represents the 'normal' elevation of pre-Old Kingdom Nilotic clay/silt contact with the Pleistocene sand. I modelled on the suspicion that the deeper clay/sand contact, around 3–4 m asl – Butzer's 'overdeepened channel(s) – might hint at artificial, Dynasty IV interventions. The boreholes show this deepest basal clay/silt appears to be meaningfully positioned with known structures of the pyramid complexes (Fig. 11.14), such as in the area between the Khufu Valley Temple and the Zaghloul Street Wall.

AMBRIC boreholes (B202 and BH60) along the path of our reconstructed Nile channel (on the course of the Libeini) show intercalated sand and clay/silt (Fig. 11.15). The silt and clay layers bottom out over solid sand, at 9.31 and 5.49 m asl (the boreholes penetrated nearly 20 m). Farther to the south, near the zone east of the pyramids and away from the wadi mouths, the lowest clay and silt layers bottom out on sand and gravel at 4.83 (B208) and 1.93 (B212). The bottom of both the Rosetta and Damietta river channels certainly featured just such variable low-water banks and depths. The deeper (summer, low water) sub-channel was usually to one side (Willcocks 1889: pl. VIII), as

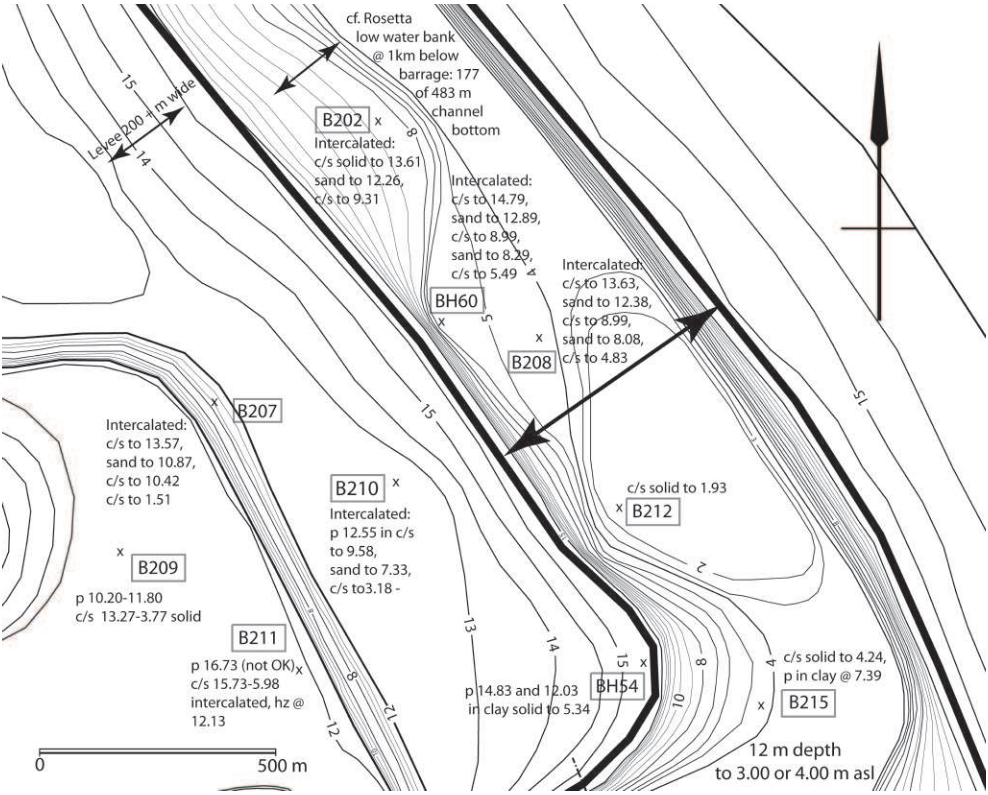

Figure 11.15 Excerpt from the reconstruction of a Dynasty IV Nile channel, 500 m wide, along the course of the modern Libeini and Marioutiyah canals, flanked by higher levee land between 12 and 16 m asl. Rectangles label AMBRIC core drillings. Accompanying notes give major strata below 16 m asl in the AMBRIC logs. Notes summarise logs of AMBRIC core drillings below 16 m asl: p = pottery; c/s = clay/silt; c/s intercalated = clay/silt interleaved with sand.

in the reconstructed channel in Fig. 11.15. With the levees rising to elevation 15–16 m asl (Lehner 2009:104–11), I derive a channel depth of more than 10–13 m, within range of the modern Nile trunk channel of 10–14 m.

As noted above, a Nile channel that followed the bend to the northwest of the Libeini as it approached Giza from the south would have delivered water slightly southwest, most probably into a central canal basin (i.e. an expanse of water where canal boats can turn and pass one another, or load and unload) that, upon certain evidence (Lehner 2014), extended to the 'gateway to the Giza Plateau' east of the Sphinx and north of the Wall of the Crow (both later than Khufu). A main Nile channel along this course lay 3.3–3.6 km from the Khentkawes basin on a line due east of the end of the Wall of the Crow. To the north, because of the northwestern angle of this Nile channel, its levees would have pressed hard against another basin, some 400 m north–south × 475 m east–west, attested by the massive Zaghloul Street Wall sections and Khufu Valley Temple pavement (Hawass 1997:248–50; Lehner 2009:105, 110, pls. 8, 10, 15).

Akhet Khufu 'Marina'

How does a Nile channel on par with the Rosetta, plus its western levee, following the course of the Libeini, impact the model of water transport infrastructure? Because of the pronounced northwest bend at the latitude of Giza, the channel feeds directly into the delivery zone at the low southeastern base of the Moqattam Formation outcrop. However, a little farther north, east of the Khufu Valley Temple location, the western levee of the Nile channel presses closer to the escarpment and low desert. If Khufu's engineers confronted a river channel like this, they needed to cut through its massive levee in order to create a basin that fronted the valley temple.

Alongside this compelling geomorphological evidence we also now have the Wadi el-Jarf Papyri (Tallet 2017:83–4, 152) with Merer's journal telling us that Khufu's engineers did create, just here, a great basin with stone dykes (Tallet 2017:40–1 [AII]). One section, BIV (Tallet 2017:63–7) is particularly critical. Inspector Merer and his phyle spend Day 21 loading an *imu*-boat with limestone in Tura North. They leave in the afternoon and sail to the Ro-She Khufu, where they spend the night. They leave the Ro-She Khufu in the morning of Day 22 to sail to Akhet Khufu (the Khufu Pyramid) and to spend the night at the Chapels (*ẖmw*) of Khufu.[54] On Day 23 an overseer of 10 (men) named Hesi, possibly a purveyor for Merer's team, who spent the day with his naval section in Ro-She Khufu, was told to set sail (to obtain provisions?). That night Merer and his phyle are back overnight at the Ro-She Khufu(?), where they spend Day 24 hauling stones or towing boats with subordinates of the 'Elite-' (Tallet 2017:63, 65, n. j.) or 'Chosen Phyles' (*spt-sꜣw*) and a work gang (*ꜥpr*) under the supervision of the noble (*jry-pꜥt*) Ankh-haf, director of the Ro-She Khufu (and, as known from other sources, overseer of all the king's works and vizier). That evening, Merer and his men return via an overnight in the Ro-She Khufu to Tura to haul stones and spend the night.

Tallet (2017:55, 84, 152) suggests the 'Chapels of Khufu' could refer to the valley temple, which must be connected to the Ro-She Khufu and the river to allow a team of sailors to come and go by boat and to spend the night. The overnight 'at the chapels' of Akhet Khufu is unusual in Papyrus B, where the team mostly overnights in the She ('Basin [or Lake] of') Khufu or in the Ro She Khufu, but in Papyrus A the team spends two or three nights in Akhet Khufu. Tallet suggests the overnights at the latter location might depend on the flooding of the entire hydraulic system that would connect basins and waterways of Khufu's pyramid complex with the Nile (Tallet 2017:66). He identifies a gigantic artificial lake immediately east of the valley temple with the She Akhet Khufu (*Š-ꜣḫt Ḫwfw*), the Lake (or Basin) of the Pyramid named the 'Horizon of Khufu'; that is, the Great Pyramid of Giza (Tallet 2017:46–7, n. 58, 83–4, 152, fig. 22). This term, She Akhet Khufu, is attested on one small papyrus fragment (A8).

When AMBRIC contractors dug a network of trenches for wastewater pipes east of the Giza Plateau, they hit Dynasty IV walls of stone and mudbrick and remains of Old Kingdom settlement. A deep, main, pipe trench along the west side of the Mansouriyah Canal crossed the basalt pavement of the Khufu Valley Temple at an elevation of between 14–14.50 m asl.[55] This is one benchmark for the elevation of the Old Kingdom floodplain. Wanting to keep the temple dry during the annual inundation, its builders would have founded it at least a 0.5–1.0 m above the floodwater, which in the last centuries rose on average 1.5 m above the lowest valley land. Subtracting 2 m from the elevation of the Khufu Valley Temple pavement brings us to an elevation for the Dynasty IV flood plain of around 12–12.50 m asl.

Without doubt, the annual deposit of Nile silt during the inundation raised the field lands 4.5–5.0 m – around 10 cm per century over the 4500 years since Dynasty IV – but we now know that the rise was not constant.[56] As the basins and channels filled, and the adjacent floodplain rose, these former large-scale waterways remained traceable as subtle depressions, like the linear trough along the Libeini channel. The contour line marking 18 m asl defined a broad, low embayment with its farthest western limit at the location of the Khufu Valley Temple (Fig. 11.16).

In 1993 the foundation of a massive limestone and basalt wall turned up in excavations for the foundations of a high-rise building immediately east of Zaghloul Street, 490 m east of the location of the Khufu Valley Temple and 930 m east of the upper edge of the Giza Plateau (Figs. 11.16–17). The wall belongs to Khufu; its basalt and limestone match the material in his upper pyramid temple and causeway (Hawass 1997:251; 1998:5–60, pl. 4b; Lehner 2009:110). Several years before 1993, Michael Jones, working with Zahi Hawass and AMBRIC, documented two other limestone wall segments in an AMBRIC trench along Zaghloul Street (Figs. 11.14 above and 11.16). The tops of these wall foundations are 15 m asl, another benchmark for the Dynasty IV waterfront. These wall segments, along with the longer stretch east of Zaghloul Street and the Khufu Valley Temple pavement, suggest a rectangular enclosure – perhaps a harbour – around 450 m east–west × 400 m north–south (180,000 sq m) framing the depression in front of the Khufu Valley Temple (Figs. 11.16–17).

However, AMBRIC trenches revealed yet more evidence of edges and boundaries of basins and waterways. Starting 55 m south of the Khufu Valley Temple, the trench along the western side of the Mansouriyah Canal cut through Old Kingdom mudbrick settlement for more than 1 km. Just north of the Abu Talib Bridge, where tourists turn west to go to the Sphinx, the trench cut a thick mudbrick wall lined with limestone, and then another such wall around 100 m farther south, near the bridge – evidently the northern and southern walls of a large building that would align with the southern side of the Khufu Pyramid. Next, about 30 m south of the bridge, the trench cut through more Old Kingdom mudbrick settlement structures in two phases (Hawass 1996:56–9). The oldest phase was founded at an elevation of 14.81 m asl.[57]

Boundaries and Bathymetry of the Akhet Khufu Basin

How did these structures relate to Khufu's harbour east of his valley temple, quite likely the *Š-ꜣḫt Ḫwfw* of Merer's journal, and how did they interact with a western Nile branch and the 7 m hydraulic lift of the inundation? The AMBRIC cores show deep clay and silt within this zone, indicating a naturally deep floodplain even before the Dynasty IV interventions (Figs. 11.14 above and 11.18). On the basis of very deep clay and silt in some of these drill cores, Butzer *et al.* (2013:3345, fig. 2C), as noted above, inferred that an 'overlydeepened' Nile channel ran directly in front of the Khufu Valley Temple in the Old Kingdom. Again, in their analysis they lack any of the benchmarks of Dynasty IV architecture and settlement known from excavation. A Nile channel just here would separate the Zaghloul Street Wall from the Khufu Valley Temple.

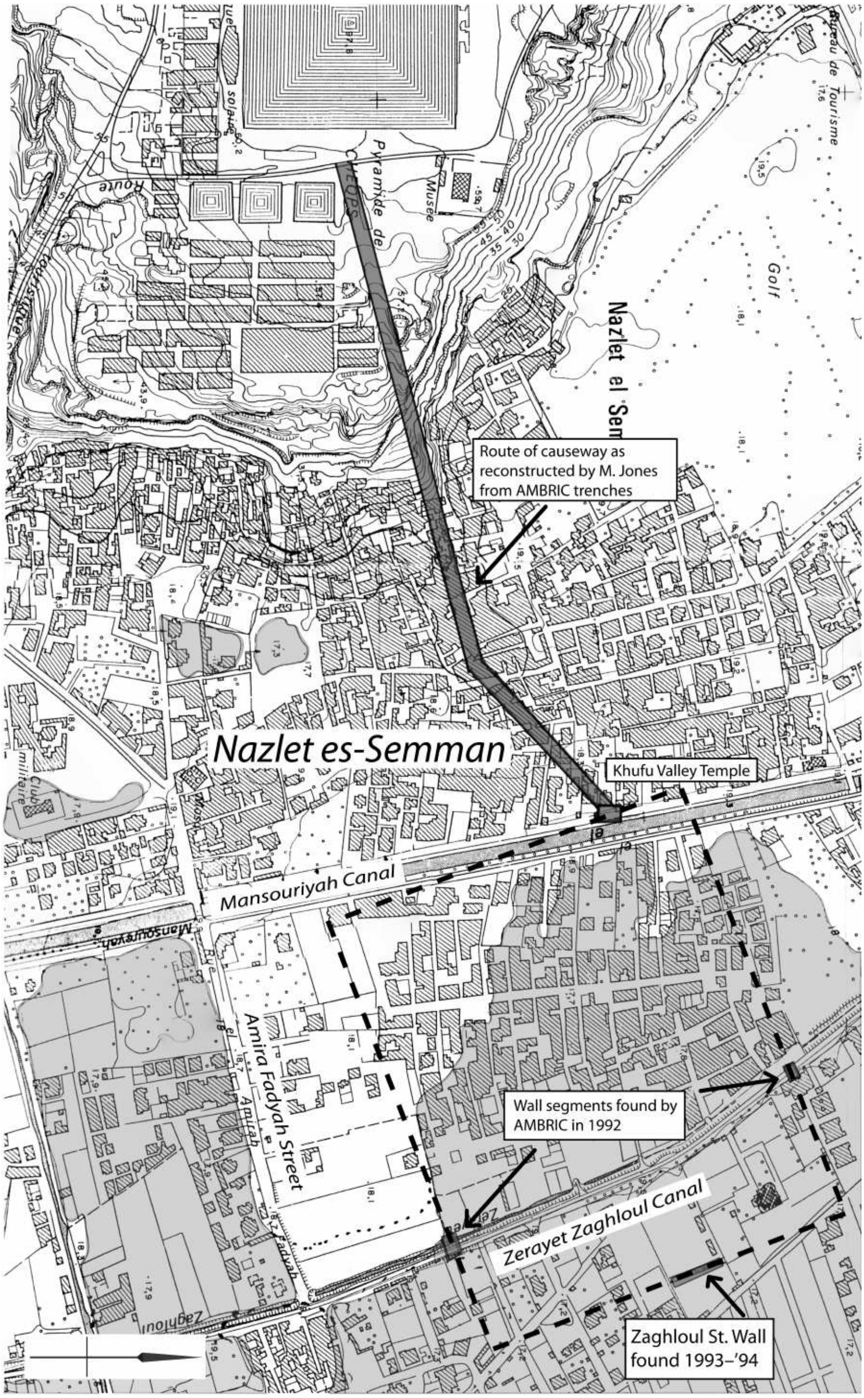

Figure 11.16 Left: rectangle projected over the stretch of the Zaghloul Street Wall found in 1993, and the Khufu causeway, shaded dark, as plotted by Michael Jones on basis of exposures its foundation in AMBRIC trenches (after Hawass 1997: fig. 1; Lehner (2009:110, pl. 15). Shaded area is the valley floor below 18 m asl.

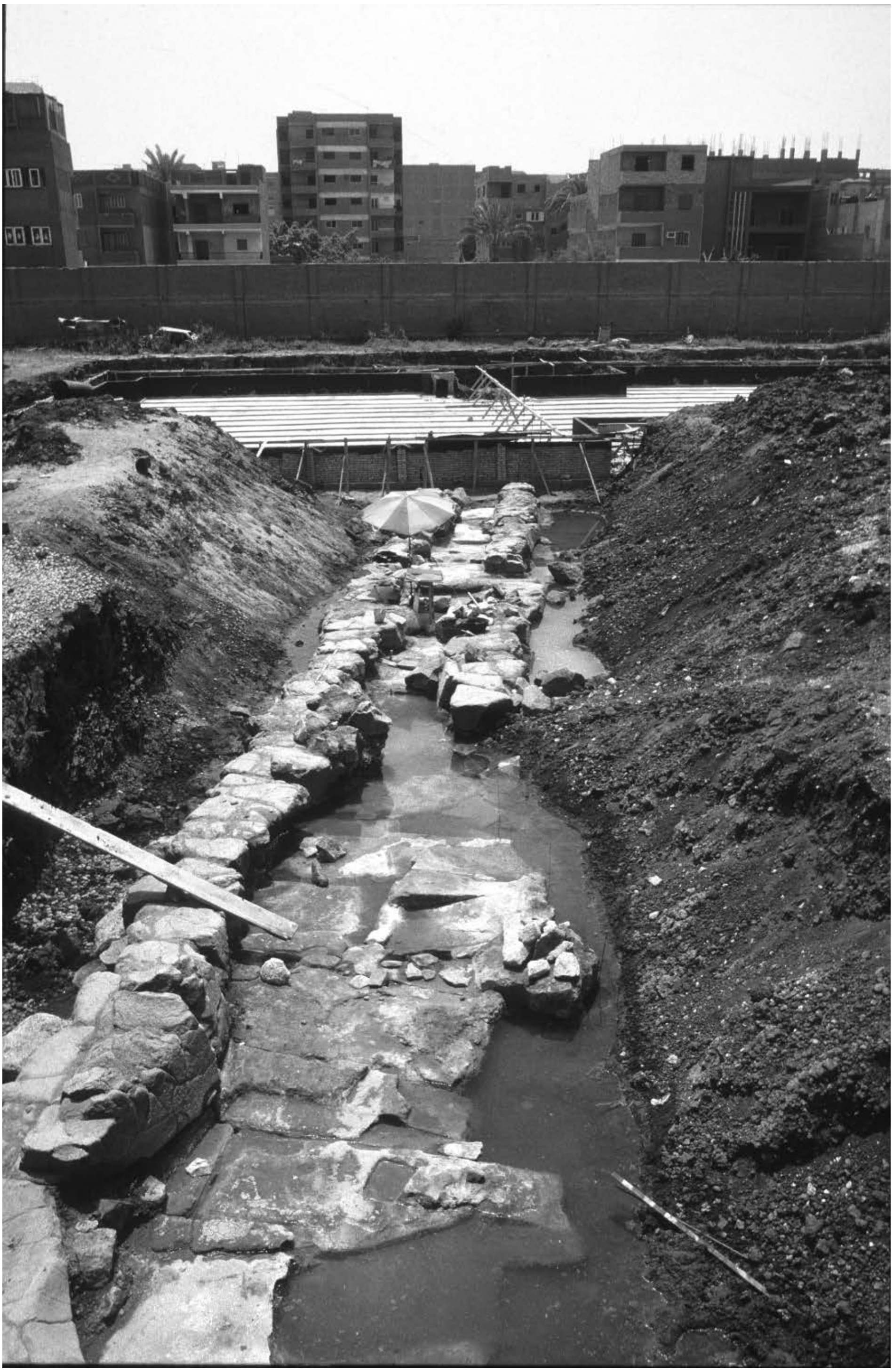

Figure 11.17 Zaghloul Street Wall, exposed in 1993, view to the south.

It is possible the two buildings stood on opposite banks of a river channel, but taken together the Dynasty IV structures suggest more a protected marina, which I have reconstructed following the Zaghloul Street Wall segments (Figs. 11.18–19).

The valley temple pavement on the west and the hypothetical large building on the southwest confine this zone. An artificial basin just here would solve what Butzer *et al.* (2013:3344–7, fig. 3E) see as a 'problematic […] fault-like displacement near the Khufu Causeway (cores [B]259–260, 264 […])'. They conclude the discontinuity 'could be a harbor infilling'. In fact, B260 (see Figs. 11.18–19) penetrated only sand from 19.80 down to 9. 41 m asl. This sand must be the low desert scree at the foot of the escarpment (AMBRIC 1989:B133). The log for B259, immediately south of the lower causeway and valley temple, shows clayey silt, pottery (red brick fragments) and limestone fragments between 14.62 and 13.82 m asl. This must be settlement material. It lies upon on a sand stratum from 13.82 to 10.72 m asl. Below this, B259 showed clay down to 8.70 m asl (AMBRIC 1989:B131). The log of B264, located farther south and east, is more complex, showing evidence of settlement (pottery, shell, limestone fragments) between at 14.19 m asl over sand to 12.19 m asl, clay and silt to 7.92 m asl, sand to 6.99 m asl and clay to 6.39 m asl, and then sand down to the bottom of the borehole at -1.81 m asl (AMBRIC 1989:B142 and B143).

In the elevation range between 14 and 16 m asl, I take the pottery, limestone and shell in silt and clay as indicating Old Kingdom settlement. Here, surely, the settlement is associated with the nearby valley temple. I follow a rule that indications of settlement in this elevation range must delimit my proposed deeper Dynasty IV basins and waterways (as opposed to shallow, floodplain-level basins).[58] So my proposed western basin edge is more to the east of this 'fault-like' displacement, on a line with the location of the valley temple (Figs. 11.18–19). The elevations of the pottery in several AMBRIC cores (B214, B259 and B264) range between 14.00 and 15.00 m asl, which I take as the higher land of the western river levee and low desert.

In reconstructing a basin east of the valley temple, which, as we now see from the Wadi el-Jarf Papyri was probably called the *Š-ꜣḫt Ḫwfw*, I took these indications of settlement and the remains of the valley temple as the western side, the Zaghloul Street Wall as the eastern side and the two additional wall fragments that Michael Jones documented in the AMBRIC trench along Zaghloul Street as the northern and southern sides. The mound of Nazlet el-Sissi served to further delimit the basin on the southeast. AMBRIC borings show extraordinarily deep clay close around this mound as well as settlement at elevations 15.65–13.95 m asl underneath the mound.

How deep was the basin east of the Khufu Valley Temple? As with the river channel, I took the AMBRIC cores as the guide. Borehole B216, which falls just to the northern side of the reconstructed basin, south of the northern Zaghloul Street Wall fragment, showed solid clay and silt from 15.84 down to 7.29 m asl, bottoming out on sand (Figs. 11.18–19). Borehole B238, at the southern side of the enclosure, showed solid clay down to 4.10 m asl, over deep sand. Taking the bottom of clay and silt as the bottom of the basin results in a bottom that slopes down to the south from 7 to 4 m asl. The lowest side is about as deep as the deepest bottom of the reconstructed river channel. If, as in previous centuries, water during the low water season lay 5 m below the floodplain (so at 12 m asl minus 5 = 7 m asl), the water in the basin was only 2 to 0 m deep during that season, and only 3 m deep

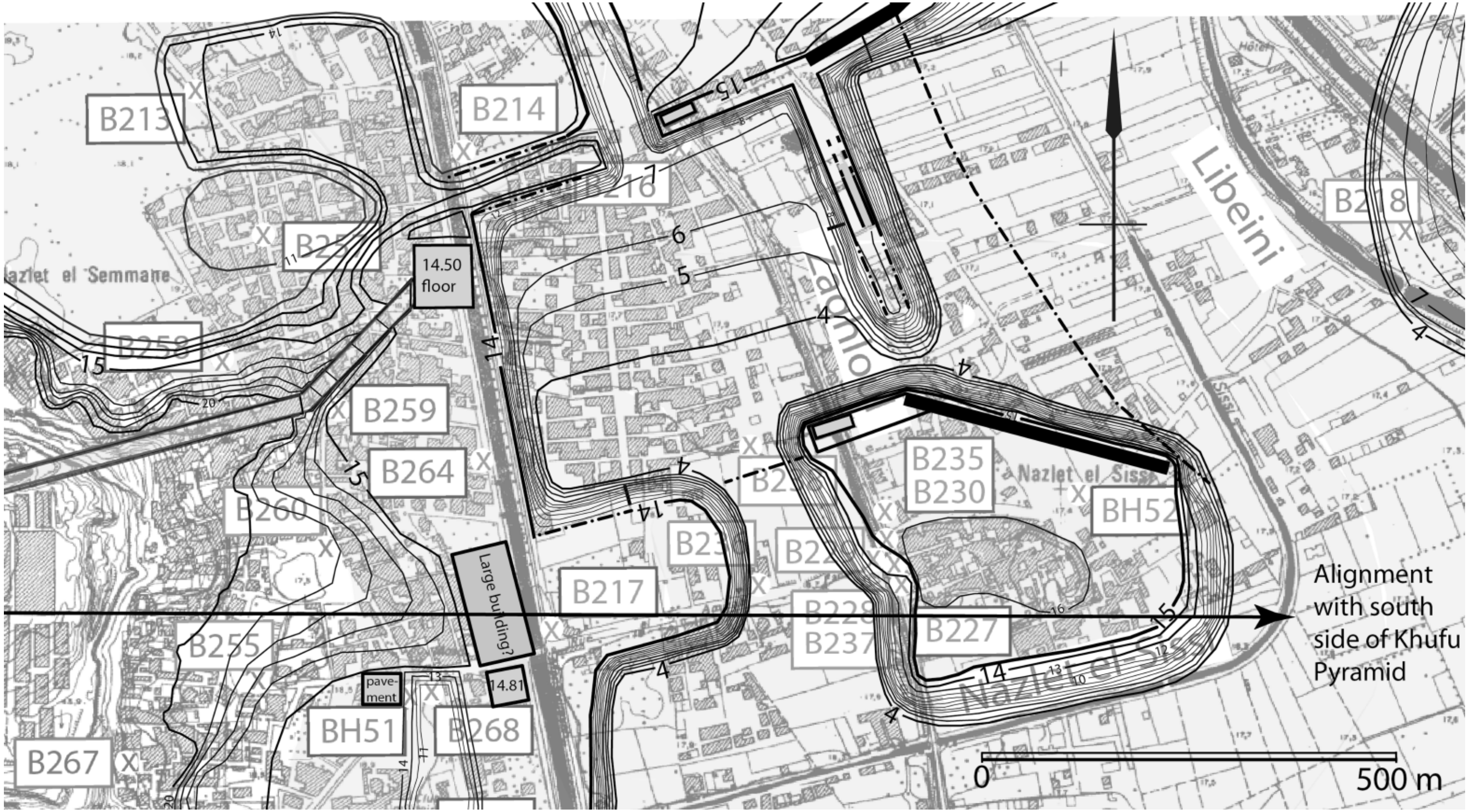

Figure 11.18 Contour lines of the reconstructed water transport structures overlaid on the 1977 MHR map of the valley floor east of the Khufu Pyramid.

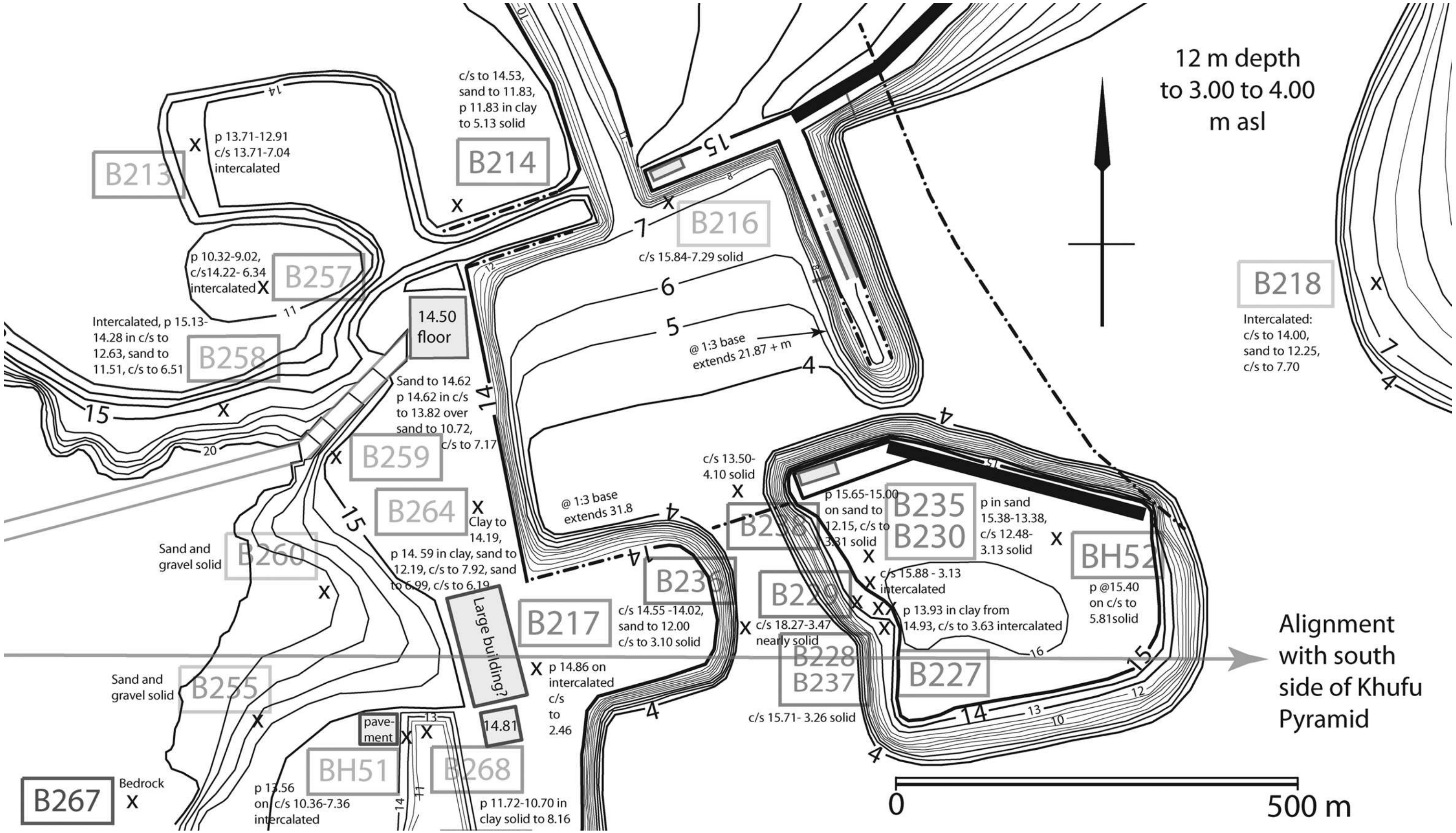

Figure 11.19 Contoured reconstruction of water transport structures east of the Khufu Valley Temple. Numbers in rectangles are AMBRIC core drillings. Notes summarise logs of AMBRIC core drillings below 16 m asl: p = pottery; c/s = clay/silt; c/s intercalated = clay/silt interleaved with sand.

in the deepest parts of the adjacent Nile channel.[59] During the inundation, however, the water would rise nearly 7 m, to a peak at 13.50–14.00 m asl, and fill the basin nearly to its brim, lapping up against the Zaghloul Street dykes and the Khufu Valley Temple.

Here we see the effects of a large Nile channel and its western levee pressed against the west. A western river bank that rose 2–3 m above the floodplain as close as the Libeini and Marioutiyah canals would dam the Khufu basin on the east, rendering it a *cul de sac*, difficult to fill and drain. Therefore, in my model I would have opened the basin to the Nile channel, but I had to do something with the long eastern stretch of the Zaghloul Street Wall. I left it upon a dyke or berm 11 m high and more than 50 m wide. Is this realistic?

Unfortunately, we do not know the base or foundation of the Zaghloul Street Wall, or whether Khufu's engineers left it upon an earthen berm that they reserved as they excavated the basin. Cutting a transverse opening through the Nile levee and dredging a basin down to low water depth would have been a prodigious task (Butzer 1976:45–6), but within the capabilities of the Giza pyramid builders, who cut the limestone bedrock more than 10 m deep for the foundation of the Khafre Pyramid at its northwest corner. They quarried three times deeper in the western part of the Central Field at Giza (Lehner 1985a:121). As for the berm, it is about the height (10 m) of the stone Wall of the Crow, which is 10 m wide. The berm, as I have reconstructed it, splays three times the height. On the west bank of Luxor, New Kingdom Egyptians excavated 11,128,940 cu m of soil from the floodplain and low desert to create the artificial, rectangular, Birket Habu basin, 2.4 × 1 km and nearly 6 m deep (Kemp and O'Connor 1974:126–8).

Alternatively, we can look to the monumental Sadd el-Kafara masonry embankment dam in the Wadi Gerawi southeast of Helwan (Garbrecht and Bertram 1983; Fahlbusch 2001; Garbrecht 2005). Audacious enough to try to stop the wadi flooding, Dynasty IV engineers built a dam more than a 100 m long, 98 m wide at base and 58 m wide at the crest. They built the dam as a core of desert rubble between two sides of stone debris cased with ashlar masonry. With all that, the dam failed (Kumar *et al.* 2014), but it shows the confidence of Dynasty IV builders in creating berms of this scale.

My proposed berm underneath the Zaghloul Street Wall would be cut from soil, albeit Khufu's engineers could have reinforced it with stone like the Sadd el-Kafara. To remain stable against water, in recent centuries canals and basins spread out on either side at least twice their height (2 base run to 1 rise). Stone rubble casings also helped. I contoured the steep banks at a ratio of 3:1 splay (run) to height (rise), where basin banks in the last century were 2:1.[60]

Seeing the need for some kind of connection to the Nile, I propose ending the Zaghloul Street Wall dyke on the south, rather arbitrarily, and leaving an opening between this end and the Nazlet el-Sissi mound (Figs. 11.18–19). Seeing a need for a wider connection to the Nile, I also suggest leaving an inlet through the centre of the south side of the basin – the direction of the Nile current. This is also a response to a cluster of core drillings that showed extremely deep clay and silt around the village mound of Nazlet el-Sissi. AMBRIC drilled a series of holes tight around this village mound to test the ground prior to installing the 'Cheops Pumping Station' off the northwest corner of the village, at the corner of Zaghloul and Amirah Fadya Streets. The extreme depth of clay and silt in the Nazlet el-Sissi corings impressed the AMBRIC subcontractors (AMBRIC 1989:10). They found silt and clay so deep they were not certain that they ever got to the bottom of it. According to Butzer *et al.* (2013:3344–6, fig. 3D) these boreholes penetrated their 'overdeepened channel'. Their proposed Old Kingdom river channel runs just through my proposed inlet, and north of the basin along the line of a small discharge canal of my reconstruction.

Core drilling B238, where I place the opening of the outlet to the hypothetical Khufu harbour (Figs. 11.18–19), shows solid clay and silt down to 4.10 m asl. Four other boreholes (B236, B229, B228 and B237), tight along the western side of the Nazlet el-Sissi mound, showed nearly solid clay and silt to elevations below 4 m asl along the line of the suggested inlet or channel. Yet, four boreholes (B235, B230, B227 and BH52) immediately to the east around the edges of the Nazlet El-Sissi village mound show pottery, which I take as settlement, at elevations 13.93–15.40 m asl, with the higher values about the level of the Zaghloul Street Wall segments. These deposits with pottery lay over the very deep clay (3.13–3.63 m asl). As with the Khufu harbour, if the very deep clay represents the dredging and later infilling of basins and waterways, over most of this place the infilling happened before these pottery deposits. These deposits could indicate post-Dynasty IV settlement, on the hypothesis that the very deep clay filled human interventions in the natural Nile clay-Pleistocene sand boundary.

However, B229 (with no pottery) and B227 (with pottery) showed intercalated sand and clay/silt – indicating the natural un-dredged sequence of wadi and Nile flood deposits. The pyramid builders founded the southern part of their settlement at the location of Nazlet el-Sissi over this natural sequence. The northern settlement ('red bricky fragments' = pottery) could have covered a dredged and backfilled waterway. The distinction between the boreholes with pottery and intercalated sand-clay/silt and those with solid clay to extreme depths suggests some kind of edge, just here.

Twin Peaks: Gateway Settlements

Nazlet el-Sissi, the 'village of the pyramid sheiks' in the Giza inundation plain, marks a very old settlement at a propitious place. In the last two centuries, a raised, sandy path, later known as Amirah Fadya Street, ran from this corner to the west, serving as the main route for visitors to the Sphinx and Pyramids, and this mounded village shows in some of the earliest photographic views across the broad sandy plain extending from the eastern escarpment of the Giza Plateau. It is 'the exact village that supplied local help to the Napoleonic expedition and intercepted all nineteenth-century visitors coming to the plateau from Cairo' (George Mutter, pers. comm.), and it has recently been described by George Mutter and Bernard Fishman, who have curated and analysed a large collection of old photographs and stereoviews of Egypt:

> Kafr [Piazzi Smyth's name for Nazlet el-Sissi] was a village perfectly situated to intercept arriving visitors as they crossed the floodplains from the Nile to the Giza pyramids, a stream of Europeans that increased dramatically following the French invasion by Napoleon. From their elevated position in the village, the headmen or 'sheikhs' would see anyone coming from miles away, meeting them en route to offer their services as guides. Thus, the people of Kafr became de facto local custodians of the Giza pyramids, and were engaged as workmen by almost all European explorers and archaeologists working on the plateau before 1900. (Mutter and Fishman 2017:10)

The 1980s AMBRIC excavations at the northwest corner of Nazlet el-Sissi for the Cheops Pumping Station exposed Old Kingdom pottery and mudbrick structures at the appropriate level for the Old Kingdom. The large building and settlement encountered in the Mansouriyah Canal trench lay under the western end of Amirah Fadya Street (Fig. 11.18 above). Farther to the west, the AMBRIC trenches encountered a mudbrick pavement just before the road opens to Nazlet el-Semman square.[61] The position of this buried (Dynasty IV?) building and the Nazlet el-Sissi mound align with the southern side of the Khufu Pyramid (Figs. 11.18–19 above).

Another village mound, Nazlet El-Batran East, rises immediately south as a companion to Nazlet el-Sissi (Fig. 11.20). Postcards and stereoviews of the early twentieth century show the village mound of Nazlet El-Batran East on higher ground north of a curved catchment basin that retained water longer, as the annual flood receded and separated this village from the larger settlement of Nazlet el-Batran West. Their raised positions allowed Nazlet el-Sissi and Nazlet el-Batran East to remain above the inundation of the low, linear swath along the base of the Giza Plateau.[62]

These mounded settlements, Nazlet el-Sissi and Nazlet el-Batran East, remind us of the twin villages, El-Beirat and Ramla el-Alqata, erected on spoil heaps at the entrance to the great Birket Habu basin that the Dynasty XVIII pharaoh Amenhotep III excavated on the west bank of Luxor, *ca.* 1370 BCE, some 1158 years after Khufu (Fig. 11.21). The mounded villages at Giza could have originated as outposts at the entrance to another artificial basin.

Central Canal Basin

I have also reconstructed a canal basin from the twin peaks of Nazlet el-Sissi and Nazlet el-Batran East to the area fronting the Sphinx and Khafre Valley Temple. Evidence suggestive of such a basin can be discerned by considering modern surface contours as vestiges of ancient features

In recent centuries, the entire zone along the Giza Plateau remained waterlogged after most of the flood receded (Fig. 11.10 above), because this land lay at the base of a lateral slope of 4 m from the western levee of the Nile, pressed against the eastern desert (Fig. 11.7 above). That is why engineers augmented the Libeini drain with the Marioutiyah Canal and installed the Mansouriyah Canal closer to the plateau. They also installed two drainage canals that point straight to the Sphinx and Khafre Valley Temple, taking advantage of a depression that runs at this orientation, slightly northeast to southwest, between Nazlet el-Sissi and Nazlet Batran (Figs. 11.20 above and 11.22).

My hypothesis is that these village mounds mark the corners of another basin that gave access to the lowest point along the southeastern base of the Giza Plateau (Fig. 11.2 above),[63] where the Khafre Valley Temple, Sphinx and Sphinx Temple were built after Khufu, and where the modern road now runs from the Sphinx up to the south-eastern corner of the Khufu Pyramid.

As late as 1977, the MHR maps (discussed above) captured two main agglomerations of settlement – Nazlet Es-Semman to the north, and Nazlet El-Sissi, Nazlet El-Batran and Kafret Gebel to the south (Figs. 11.14 above and 11.22) – carrying on a tradition of a northern and a southern Giza settlement that we see in Old Kingdom titles of town administrators (Lehner 2016:111–18). As the annual inundation decreased after

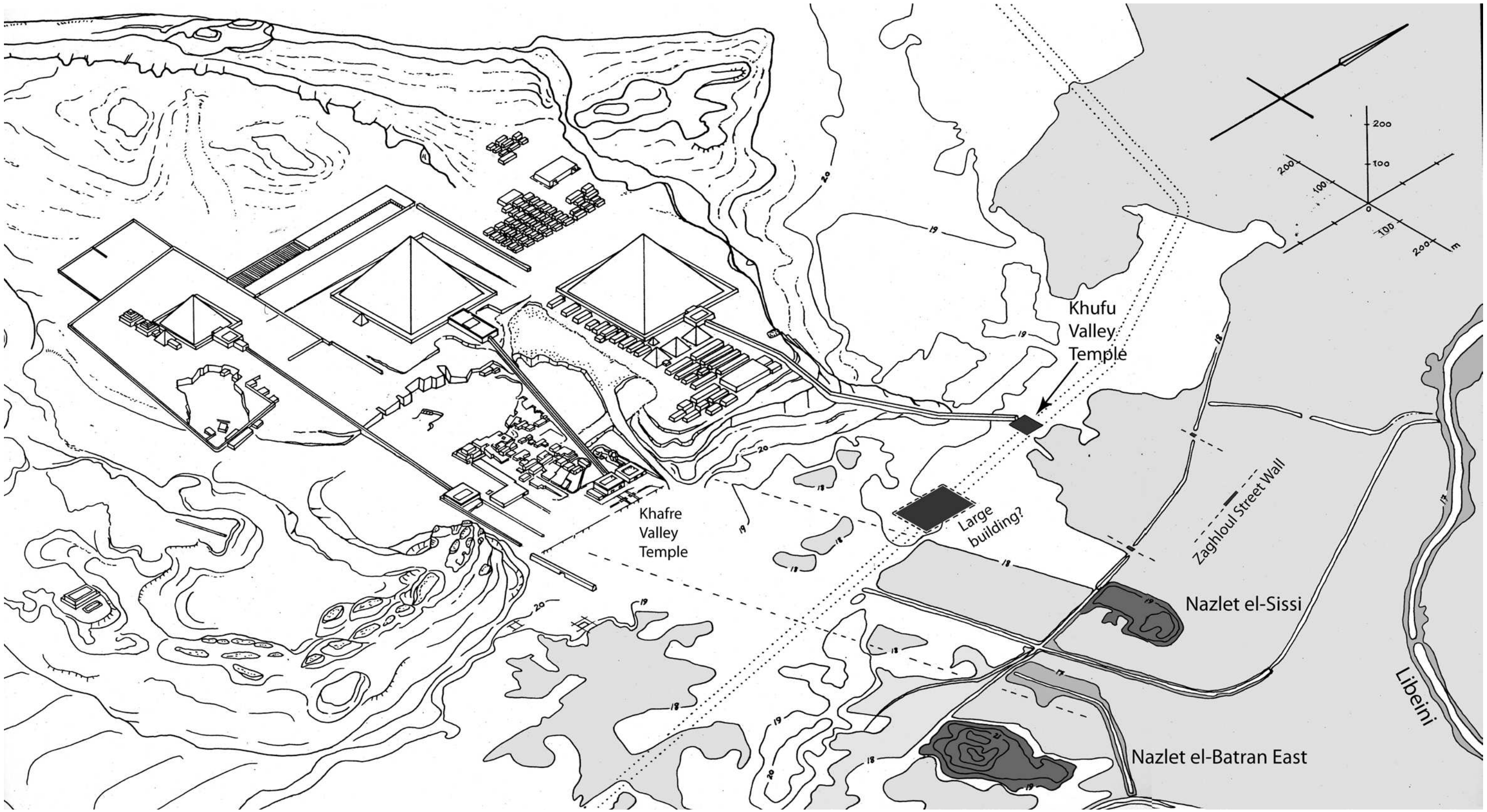

Figure 11.20 Mounded settlements of Nazlet el-Sissi and Nazlet el-Batran East rise in the modern (1977) contours of the Giza floodplain. Grayscale for land between 18 and 17 m asl shows subtle depressions extending toward the Khufu and Khafre Valley Temple locations.

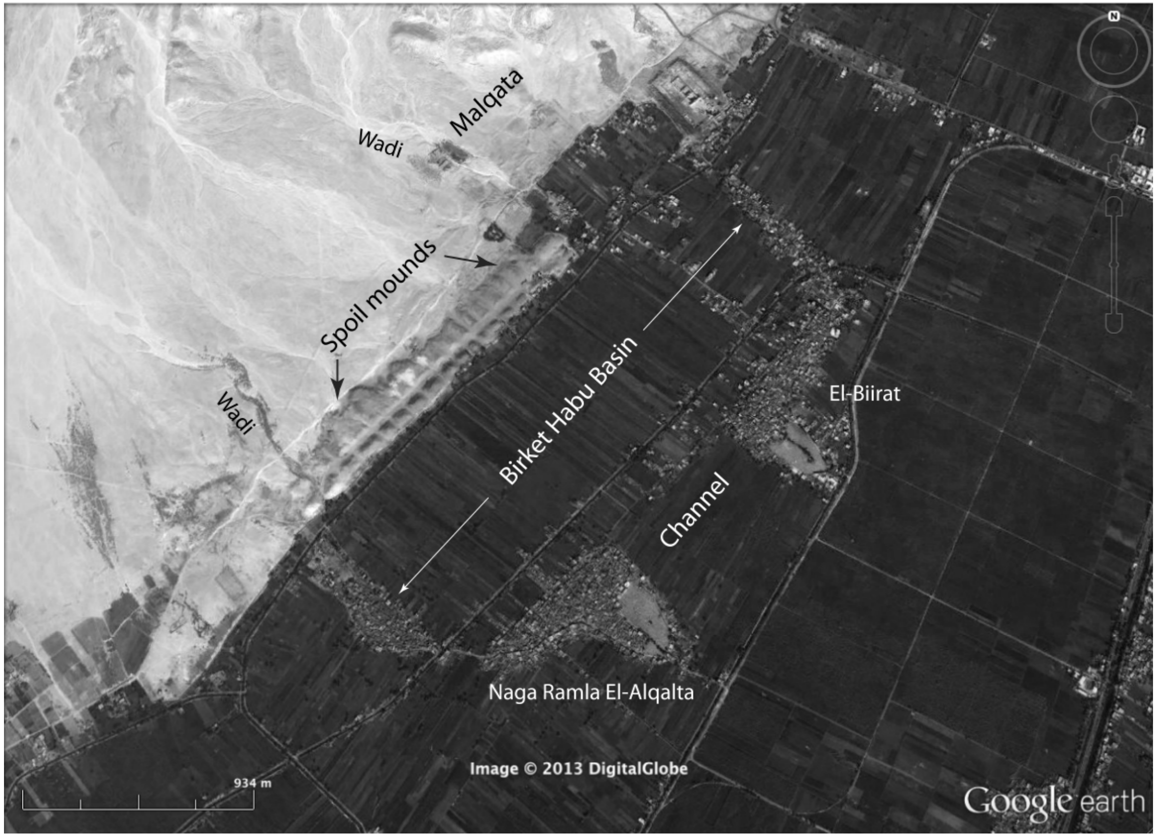

Figure 11.21 Birket Habu basin, 2.4 × 1 km, at Malqata, Luxor. While excavating the basin for the New Kingdom pharaoh Amenhotep III, workers heaped up spoil mounds that rise up to 14 m above the modern surface in two rows on the west, and linear berms on the northeastern and southwestern ends. Two mounds flank the channel-like entrance, 730 m wide, which appears to have simply opened onto the floodplain. The modern villages of El-Beirat (or El-Biirat) and Naga Ramla El-Alqata occupy the corner mounds flanking the channel. A similar pattern is seen in the two mounds flanking the central canal basin in the reconstructed floodplain at Giza (image from Google Earth).

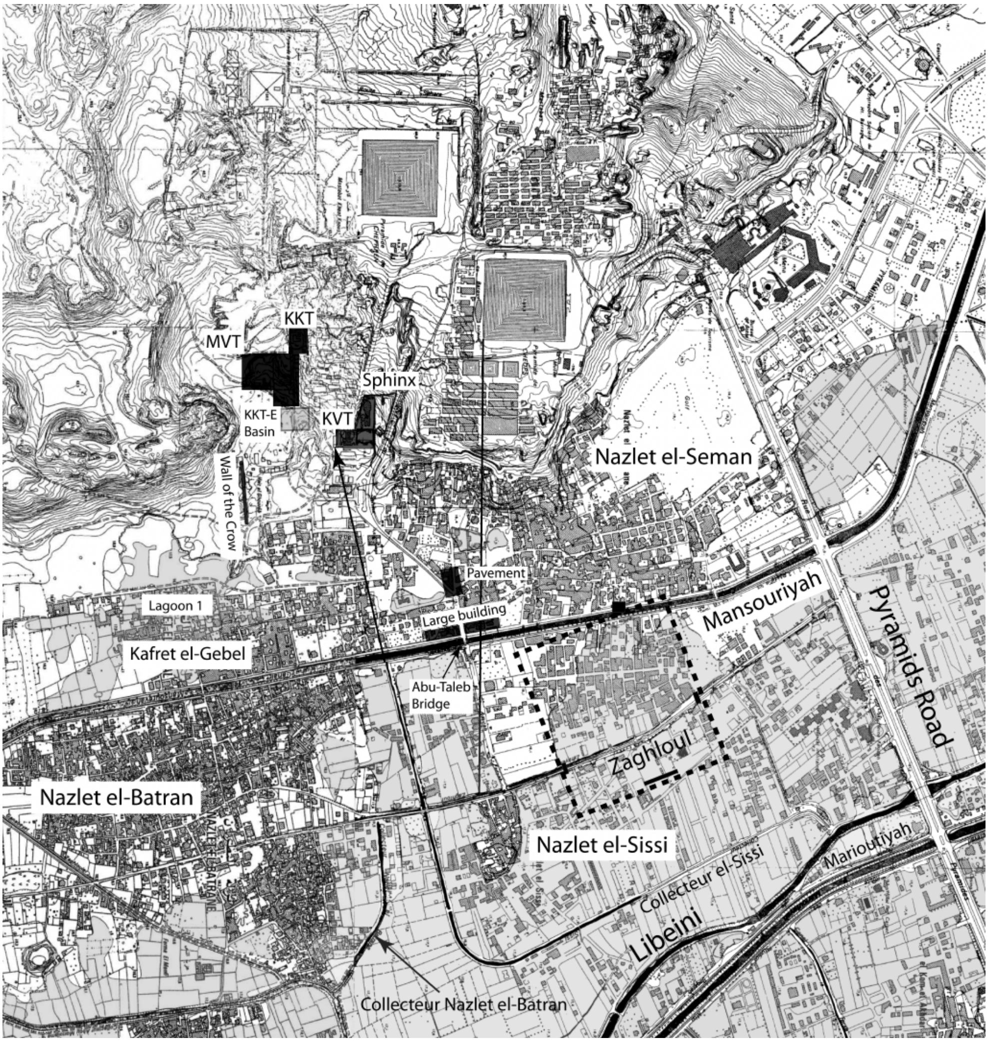

Figure 11.22 Extract from the 1977 MHR map showing the floodplain below and east of the Giza Plateau. The zone of proposed Old Kingdom Nile channels lies between the modern Mansouriyah and Marioutiyah (Muhit) canals. The Libeini is considered a relic Nile channel. Modern settlement (dark grey), 7–13 years after the last Nile floods at this latitude, expands from two concentrations: north around the Khufu Valley Temple location (Nazlet el-Seman) and south and east of the Wall of the Crow and Heit el-Ghurab site. The hypothesised ancient canal basin and the modern Collecteur el-Sissi canal run through the gap between the two modern concentrations of settlement. Buried and exposed Old Kingdom architectural elements are shown in black. Greyscale indicates land below 18 m asl. KKT = Khentkawes Town; KKT-E = the basin east of KKT; KVT = Khafre Valley Temple.

the Egyptian government built the first Aswan Dam between 1898–1902, and after the inundation stopped when the High Dam was completed between 1960 and 1971, Nazlet El-Batran began to spread farther south and west and merged with Kafret Gebel. Another agglomeration, Nazlet Es-Semman, spread down onto the floodplain from 'butterfly wings' of high ground flanking the Khufu Valley Temple location (Fig. 11.22; see Lehner 1985a:113, fig. 3A, 117, no. A19).

Taking advantage of the low ground in between the two settlement concentrations, engineers dredged two east–west drainage canals in the 1930s (when they also made the north–south Mansouriyah Canal): the Collecteurs Nazlet el-Batran and Nazlet el-Sissi (Figs. 11.14 above and 11.22). They point directly to the Sphinx, toward the Khafre Valley Temple and toward the best route up to Khufu's Pyramid platform passed the north side of the Sphinx. The engineers of the 1930s simply followed the path of least resistance.

I asked myself whether this trough between modern settlements north and south hint at an ancient canal basin dredged by engineers 4500 years earlier. Between the two very old mounds of Nazlet el-Sissi and Nazlet el-Batran East (Fig. 11.20 above), the low land, its linearity and its orientation straight toward the Sphinx and Khafre Valley Temple hint at a large, buried *canal basin*.

AMBRIC drilled one borehole B219 (Figs. 11.23–24) on this axis, slightly northeast of the central wadi between the Moqattam and Maadi Formation outcrops and midway between the village mounds of Nazlet el-Sissi and Nazlet el-Batran East. B219 shows sand from elevation 15.96 to 13.61 m asl, clay between 13.61 and 13.11, then sand to 12.01 m asl. We should expect interleaved sand and clay/silt east of a wadi mouth. However, the pyramid builders drastically quarried the central wadi. Farther up the wadi to the west, near the Menkaure Pyramid, they dammed the wadi with a massive embankments and berms (see above). It is doubtful the wadi ever flowed after this, meaning that it was probably after the Old Kingdom that wind delivered the upper sand layers recorded in B219. From 12.01 m asl – the estimated level of the Dynasty IV flood plain (Lehner 2009:142) – down to 3.81 m asl, B219 shows solid clay, bottoming out at a depth comparable to the core drills around the Nazlet el-Sissi mound. Here, centuries of Nile floods filled an ancient cut with clay.

At the other end of the reconstructed canal basin, the Ministry of Irrigation, Institute of Underground Water, drilled with a core sampler 68.38 m east of the Sphinx Temple (Figs. 11.23–24) in 1980.[64] The drilling began on 11 September 1980, from an elevation of 19.72–19.74 m in the sandy surface. The core sampler pulled up sand to a depth of 9 m, down to 10.73 m asl, then grayish-black limestone fragments to a depth of about 10 m. The drill bit and core sampler seemed to grind on a hard surface, as though it had descended against a rocky edge. From a depth of 12–15 m (7.72 to 4.72 m asl) the sampler brought up sandy grey clay, then concentrated grey clay with limestone fragments at 15 m depth, followed by dark grey clay slurry with non-limestone gravel to 16 m depth, 3.74 m asl. At this elevation, the core sampler brought up a palm-sized fragment, and then small bits, of red granite.

I took AMBRIC boreholes that yielded pottery at predictable Old Kingdom levels as delimiting the width of the canal basin (Fig. 11.24). To the north of the canal basin, AMBRIC boreholes B261 and B265 yielded pottery at 14.86 and 14.77 m asl. On the rule that pottery = settlement or a Dynasty IV living surface, the canal basin cannot

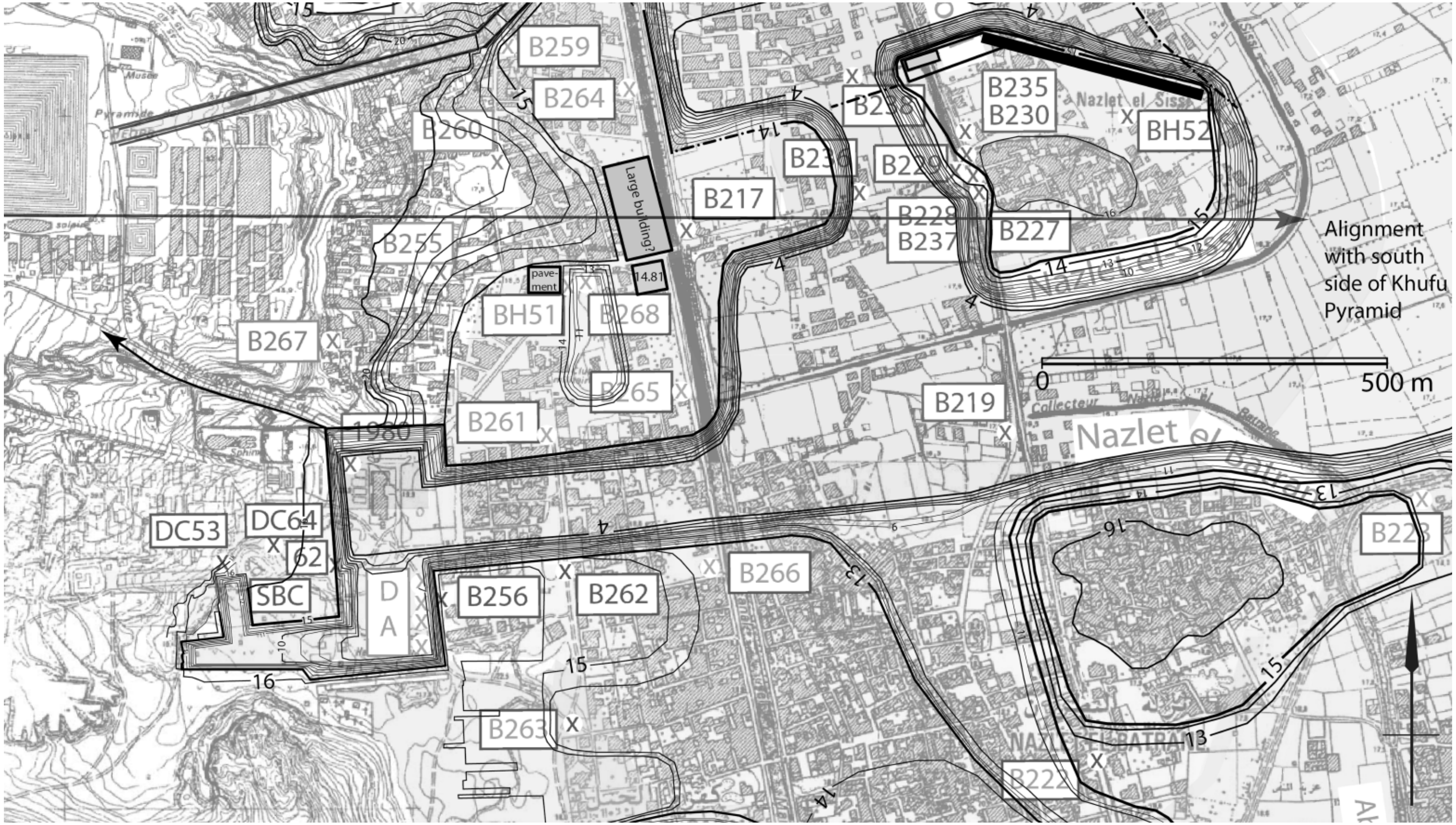

Figure 11.23 Contour lines of the reconstructed water transport structures overlaid on the 1977 MHR map of the valley floor east of the Sphinx and Khafre Valley Temple and extending to the Menkaure Valley Temple and Silo Building Complex (SBC) east of the Khentkawes complex. 1980 = a core drilling in that year; B numbers = the AMBRIC drill cores; D A = four drill cores carried out in the bus parking lot in 2011; DC numbers = shallower drill cores carried out by Serena Love with a hand auger in 2002.

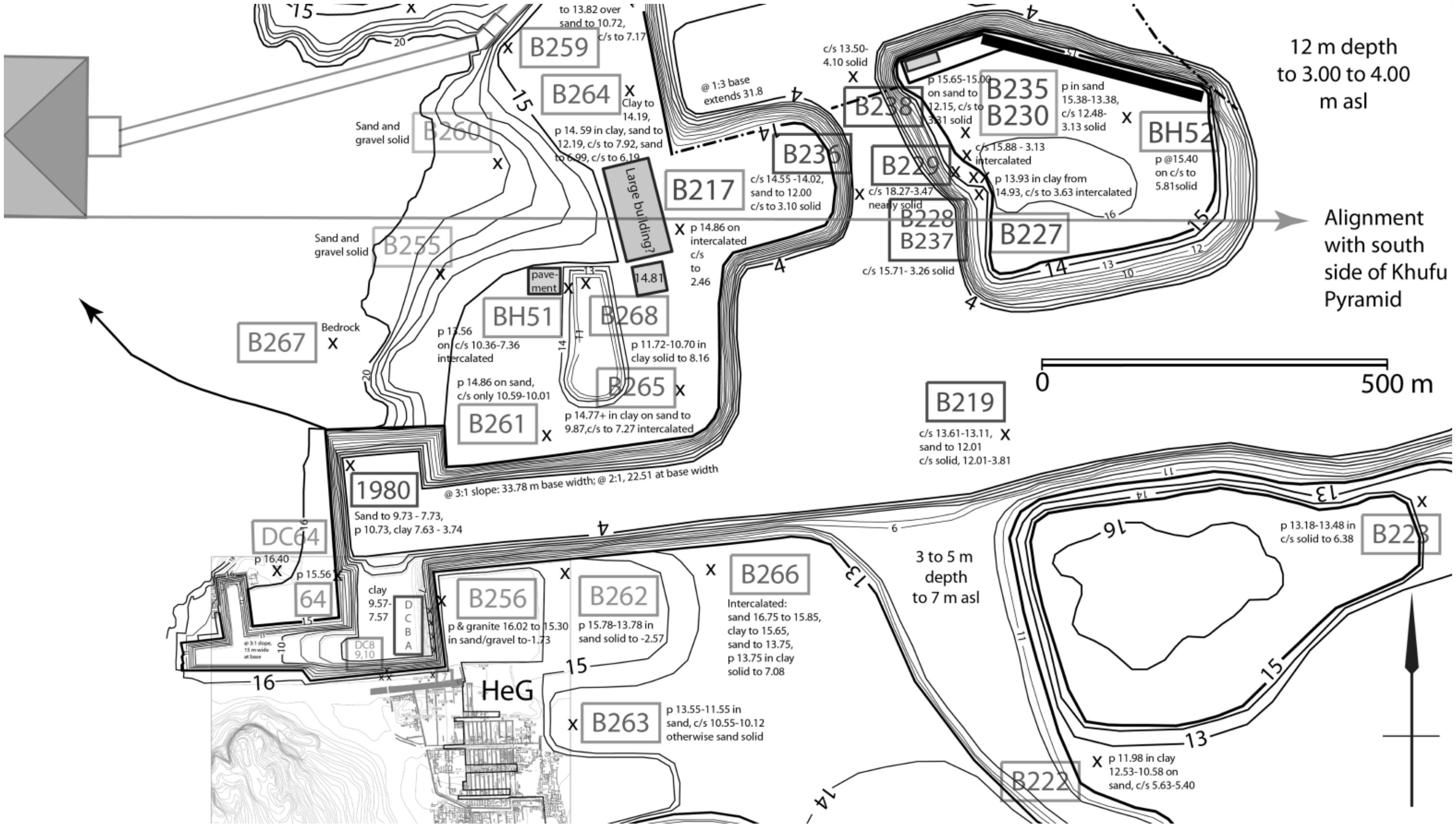

Figure 11.24 Contoured reconstruction of water transport structures east of the Khufu Pyramid. 1980 = a core drilling in that year; B numbers = the AMBRIC drill cores; D, C, B, A = four drill cores carried out in the bus parking lot in 2011; DC numbers = shallower drill cores carried out by Serena Love with a hand auger in 2002. Notes summarise logs of AMBRIC core drillings below 16 m asl: p = pottery; c/s = clay/silt; c/s intercalated = clay/silt interleaved with sand. HeG = Heit el-Ghurab.

extend further. Also, these boreholes show lower sand intercalated with clay/silt, perhaps the natural sequence prior to Dynasty IV interventions.

It should be noted that the elevations of pottery (Fig. 11.24) in B261 and B265 cohere with 14.81 m asl for the base of the settlement documented in AMBRIC's Mansouriyah Canal trench and the pottery at 14.86 in B217 nearby. Between this exposure of Old Kingdom settlement and a patch of mudbrick pavement found under the central square of Nazlet es-Semman, where the road to the Sphinx turns southwest, BH51 and B268 yielded pottery at deeper levels, respectively at 13.56 and 11.72 to 10.70 m asl. Contouring the surface to these levels results in a depression between the exposed settlement and pavement. The large building encountered in the Mansouriyah Trench lies buried immediately northeast. We can only imagine a large royal building flanked on the south by other structures around a shallow basin.

Respecting these features, and on the rule that pottery in boreholes between 12.00 and 15.00 m asl marks a Dynasty IV living surface, my proposed reconstruction features a widening at the eastern mouth of the canal basin and a narrowing to 135 m to its western end. Pottery and other settlement indicators (such as imported granite) in B256, B262 and B266 give a higher southern bank, sloping down to the east, at elevations 16.30 to 15.30 m asl (B256), 15.78 to 13.78 m asl (B262), and 13.75 m asl (B266).

We can hypothesise that the Pyramid builders left this southern bank as part of the original sand/gravel fan emanating from the central wadi and the low desert of its time, while they dredged deeply along the north to create the canal basin, more than 350 m long. They may have raised the southern flank as a spoil bank from their original dredging of the wadi mouth (see Fig. 11.14 above). B256 and B262 penetrated solid sand or gravel – no clay or silt – as deep as -1.73 and -2.57 m asl. Farther east, into the floodplain, B266 yielded intercalated sand and clay/silt to 13.75 m asl, the level of the pottery (= Old Kingdom settlement); below this, there is solid clay and silt. Farther south, B263 – only 40–50 m east of our exposure of the Dynasty IV Heit el-Ghurab settlement (Fig. 11.24) – penetrated a layer of silt only 43 cm thick at 10.55 m asl, and otherwise only sand. The pyramid builders extended the Heit el- Ghurab settlement and infrastructure upon the raised, southern spoil bank, in peninsular fashion, south of the major delivery zone and alongside their deeply dredged canal basin.

The position of the 1980 borehole (Figs. 11.14 and 11.23–4) demands that we extend the northern end of the canal basin north, but only so far as the northern ledge of the quarried Sphinx ditch. This ledge forms the northern boundary of the terraces of the Sphinx and of the lower Sphinx Temple and it extends 30–40 m east beyond the temple, where it disappears under the modern road. Just here, the contours of the plateau show a ramp-like protrusion of material banked against the corner of the escarpment. This protrusion and the modern road correspond to an ancient way up onto the plateau and the area between the Khufu and Khafre pyramids (Fig. 11.2 above). On the north of the waterway leading to this access, Old Kingdom settlement, as indicated in boreholes (BH51, B268, B261 and B65) as well as by the exposures of Old Kingdom structures in the AMBRIC trenches, occupied a platform along the northern side of the canal basin. In these buildings, officials controlled access and accounted for deliveries.

If the T-shaped basin extended south already in the time of Khufu, his forces could have delivered materials across the places later occupied by the Khentkawes valley complex and Menkaure Valley Temple along the northern rim of the central wadi. I leave the evidence and inferences for reconstructing that southern extension, and the additional westward extension to the Khentkawes basin and Menkaure, for another discussion.

Ro She Khufu (R-š Ḫwfw)

Where in this visualisation shall we place the Ro She Khufu? *R-š Ḫwfw* is a regular overnight stop of Merer and company when they come from and go to Tura North, but not, however, on the trips to and from Tura South. *R-š Ḫwfw* is simultaneously a water station, a port, and as ports have been through many times and places, an administrative centre.

While accepting the 'immense lac artificiel' east of the valley temple as *Š-3ẖt Ḫwfw*, Tallet (2017:83, 151–2, fig. 22, citing Lehner 2013; 2014) considers the intriguing suggestion that *R-š Ḫwfw* could have been the name, in Khufu's time, for the Heit el-Ghurab site. He cites the galleries, and our hypothesis that they served as barracks-like accommodations for gangs, crews and phyles of about 40 members. A phyle of about 40 men like Merer's, according to Tallet's (2017:87, 155) estimate, would have just fit inside one of the galleries, which is consistent with our own estimations (Lehner 2002:69, fig. 20). Tallet sees a fit between his estimate for the number of men in Merer's phyle, as a basic group-unit, and the formation of phyles from smaller divisions into larger gangs based on information in the Wadi el-Jarf Papyri, and our estimates for numbers of divisions, phyles, and gangs based on builders' graffiti and the Heit el-Ghurab gallery system (Tallet 2017:43–4, 59–60, citing Lehner 2015b:432–8).

I have argued that the Heit el-Ghurab site was the referent for the toponym *ṯnj rśj* in titles of administrators at Giza, such as the title of Nesut-nefer (G 4970), *ʿḏ-mr ṯnj rśj* governed by the name of the Khafre pyramid: 'Administrator of the Southern Desert Edge Settlement', or, 'Settled Border', 'of the Pyramid "Great is Khafre"' (Lehner 2016:113–16). In his comments on the term, Junker (1938:176) already pointed to the as-yet unexcavated Heit el-Ghurab site, beyond the Gebel el-Qibli and the Wall of the Crow. The site fits Edel's (1956:70) specifications for the referents of the term *ṯnj* as desert-edge highland, or even '*Gebirg*' ('mount'). Stadelmann (1981:69–70) saw the *Ṯnj rsj* as one of a contrastive pair with a northern *grg.t* ('settlement') associated with Khufu. He understood these terms as early names of the settlements attached to the pyramids of Khafre and Khufu, the names of their proto-pyramid towns. I have suggested that the northern *grg.t* of Khufu was located on highland flanking the Khufu Valley Temple (Lehner 2016:117–18). However, no attestation of either *grg.t* or *ṯnj rśj* is found in the Wadi el-Jarf Papyri that comprise Merer's journal (Tallet 2017:137–8).

To date we have found no sealings of Khufu from excavations at Heit el-Ghurab: 'Out of more than 5,000 clay sealings recovered from the site, only five belong to a king other than Khafre or Menkaure. All five date to the reign of Userkaf, the founding ruler of the 5th Dynasty' (Nolan 2012:3; see also Nolan 2010:23, 60; 2011:12). However, in a number of places we have exposed an older phase of the site, with a markedly different organisation than the main phase that we have so far mapped and excavated (Lehner and Sadarangani 2007:67–72; Lehner *et al.* 2009b:49–59). From our largest exposures of the older phase, it is clear that builders dismantled structures before rebuilding. The galleries we have mapped and excavated date mostly to the main Khafre-Menkaure phase, although the northern Gallery Set I may be earlier. They are 55 m long, in contrast to the galleries in Gallery Sets II–IV, which are 35–6 m long. Our excavations at the northwestern corner of Gallery Set I, at the eastern end of the Wall of the Crow, shows underlying, older phases – the Wall of the Crow itself is certainly later than Gallery Set I (Lehner 2002:51). The fact that we have found earlier phase structures below two major buildings – Galley Set I and the so-called Royal Administrative Building – at the far northwest and southeast corners of Heit el-Ghurab suggests the older phase spanned this entire zone.

We have found no sealings bearing Khufu's name in the older phase. However, we have yet to excavate down through its floors and foundations. We hold as a working hypothesis that the massive dump of disarticulated settlement debris that Karl Kromer (1978) excavated behind (southwest of) the Gebel el-Q̱ibli, on the western side of the Maadi Formation escarpment, may derive from the demolition of the early phase architecture on the Heit el-Ghurab site, just prior to its reorganisation late in the reign of Khafre or early in the reign of Menkaure (Lehner 2018; Witsell 2018), although Kromer thought this material derived from a settlement that Menkaure's builders removed from the site of his Menkaure Valley Temple. From our excavations of Heit el-Ghurab we have sealings of Khafre and Menkaure, but none of Khufu. From this dump Kromer (1978:114) retrieved sealings of Khufu and Khafre, but none of Menkaure. We plan further work at the site of Kromer's excavation, while expanding excavations of the lower, older phase of the site.

Whether or not the Heit el-Ghurab older phase dates to Khufu's reign, Tallet (2017:84) sees the proximity of the site to the Khufu Pyramid as 'rédhibitoire' for identifying Heit el-Ghurab with *R-š Ḫwfw*. If the offloading place was as close as the base of the Moqattam Formation outcrop where the Khafre Valley Temple and Sphinx were later created, this is very close to the Heit el-Ghurab. Yet, Merer and his team take a second day of sailing from *R-š Ḫwfw* to *3ḫt Ḫwfw*, a day that includes offloading the blocks, which is only once mentioned (Fragment B22). This means *R-š Ḫwfw* and Heit el-Ghurab must be distinct and somewhat farther from each other than the latter and the area east of the Sphinx. Tallet suggests that any settlement at Heit el-Ghurab in Khufu's reign may have been known as *ȝḫt Ḫwfw*, the generic name for the whole building site/necropolis. Alternatively, Heit el-Ghurab could have been the place named Ankh Khufu, determined with a *niwt* (town, village) sign, or this could have been the more northern settlement associated with the Khufu Valley Temple. Ankh Khufu was evidently a settlement of some kind that Merer and his team passed by after visiting *R-š Ḫwfw* and *3ḫt Ḫwfw* (Tallet 2017:75–6, 84).[65]

Tallet goes on to write that *R-š Ḫwfw* must have given access to a great artificial lake excavated at the base of the Giza Plateau, yet it should be within a radius of 10 km of the funerary complex of Khufu. As this place is a stop on Merer's trips from Tura North, it should be somewhere out east of the grand basin that reaches the base of the Giza Plateau (Tallet 2017:84–5, 152–3). He hypothesises the gateway between villages of Nazlet el-Sissi and Nazlet el-Batran for the location of the *R-š Ḫwfw* (Tallet 2017: fig. 22). Here, and a little farther out, is the great cut through the western Nile levee, just inside the Libeini bend.

Hydraulics of *R-š Ḫwfw*

R-š Ḫwfw must have been a strategic control point for putting water transport infrastructure at Giza into operation at just the right time during the Nile inundation, when the water would rise by 7 m. Tallet (2017:85) summarises indications from Merer's journal that his team helped put the hydraulic ensemble into action by means of 'la levée d'un barrage aménagé à l'entrée d'un canal'. Bathymetries of the current model (Figs. 11.1, 11.18–19 and 11.23–4, all above) would make the seasonal building and removal of a temporary dam across the breach through the western Nile levee another truly prodigious task.

Section AII of the Wadi el-Jarf Papyri documents that Merer spent a ten-day period with his phyle working on (*ẖryw-ʿ*) the dyke or dam (*ḏnt*) of Ro-She Khufu. On Day 13 Merer and his phyle joined some 15 phyles, subdivisions of *ʿpr* gangs, perhaps amounting to 600 additional men. On Day 17 the team removed wooden piles, or bollards, of the dyke (*šdt mnjwt nt ḏ[nt]*) in the company of this large workforce and under the supervision of an important official, most probably Ankh-haf (Tallet 2017:40–6), whose name, as discussed above, is preceded in the papyri by the title *i̓ry pʿt* and is followed by the title Director of the Ro-She Khufu (Tallet 2017:63 [BIV]).

Even if my proposed reconstruction of the protected 'Khufu marina' with its apertures and massive eastern dyke under the Zaghloul Street Wall is somewhat arbitrary, and not exactly what Khufu's engineers created, it seems striking to me to have found on the ground a monumental stone wall, and fragments of other stone walls, which together define a 400 × 450 sq m enclosure, and then to have found that textual references to water transport infrastructure at Giza include the dyke (*ḏnt*), or dam, or embankment, of the Ro-She Khufu. However, if we must distinguish between the basin east of the Khufu Valley Temple, as the *Š ꜣḫt Ḫwfw*, from the *R-š Ḫwfw*, and if the dyke mentioned is 'of' (*nt)* or 'in' (*m*) the *R-š Ḫwfw*, then the Zaghloul Street Wall cannot be the remains of the dyke in question.

Tallet sees Merer's operation as documented in Section AII of the Wadi el-Jarf Papyri as the Dynasty IV equivalent of how Egyptians would dam and then open seasonal canals in more recent centuries. He cites John Cooper's (2014:120) description, derived from Parsons (1808:309–11) of how in the early nineteenth century CE people dammed the main Cairo canal. At low water (February), when the canal was drained, they built a barrier of planks about 8–10 yards (7.3–9.1 m) back from its opening to the Nile. To buttress the barrier, they used long poles, one end against the planking and the other fixed either into the bed or the banks of the canal. They filled the space between this barrier and the bank of the Nile with earth that masked the opening of the canal to anyone looking from the river. Halfway to the tops of the banks, they built upon the fill a series of vaulted brick culverts, which they closed with sluice gates, and buried in the rest of the fill. On 15 August, near the peak of the inundation, some people would pull on ropes to raise the sluice gates, while on the other side, people would pull ropes tied to the poles to yank them away. A torrent of water would then wash way the earthen fill and the planks.

As Tallet recognises, the techniques that the Dynasty IV Egyptians used to dam and open the heads of canals probably differed, but he suggests that when Merer and his men removed the wooden poles, or bollards, they may have been opening the basins

– for which Ro-She Khufu served as gateway – to the Nile inundation so that crews could deliver stone by boat during the high water season: 'Cette opération est cruciale, car elle correspond dans ce cas véritablement à la remise en service de la voie d'eau qui permet d'accéder au chantier de la pyramide, et pourrait marquer ainsi le coup d'envoi de sa campagne d'approvisionnement en gros blocs venus de la rive opposée du Nil' (Tallet 2017:46).

However, we still have to draw certain practical observations about the comparison between opening the head of the Cairo Canal in the 1800s and the entrance of the Khufu basin at Giza some 4300 years earlier. I am not certain if the head of the Cairo Canal or the heads of other major seasonal waterways were as deep as the main Nile channel(s) in pre-modern Egypt.[66] In my proposed reconstruction, I envision the beds of the central canal basin, its widening and inlet along the west side of Nazlet el-Sissi, at the same depth as the Nile channel, 4 m asl. This is on the basis of the bottoming-out of the very deep clay and silt in the AMBRIC and 1980 core drillings. The opening from the Nile channel (on the Libeini bend) is wider than the central Giza basin, similar to what Parsons wrote regarding the Cairo Canal: '[T]he aperture at the entrance, which continues for more than a mile, is more than double the breadth' (Parsons 1808:309). In the model, the opening from Nazlet El-Sissi to Nazlet el-Batran East is 250 m across and 11 m deep (15 to 4 m asl). To dam this access with timbers and earth would be a prodigious task before each flood season, albeit perhaps not entirely beyond Khufu's capabilities.

Rather than being made from the more common acacia, tamarisk and palm, wood poles for bracing a temporary dam would have to be cedar, which grows to heights of 30–40 m. Planks in the Khufu boat retrieved from the eastern pit on the south side of the Great Pyramid measure up to 22.73 m long (Gale *et al.* 2000:349). The ancient Egyptians constructed utilitarian structures, such as transport sleds, from cedar planks up to 31 m long (Arnold 1991:278). This shows that Khufu's workers could have used wooden struts and bollards 11 m long, the depth of any gateway between the twin mounds flanking this proposed *r-š*. However, 250 m is more than twice the 110 m span of the Sadd el-Kafara Dam in the Wadi Gerawi. That dam, which was probably not intended to be seasonal, rises 14 m high and spreads 98 m at its foot (Garbrecht and Bertram 1983).

My reconstructed outlet just west of Nazlet el-Sissi, 160 m wide and 10 m deep (14 to 4 m asl) to river depth, would have been a bit more tractable to block and open seasonally. The reconstructed (and arbitrary) aperture off the south end of the Zaghloul Street dyke, 10–15 m wide at bottom and nearly 100 m wide at top with the splay of the bank, would have been even easier to block.

A large, main, Nile channel pressed against the west gave a hydraulic advantage to the delivery and lifting of heavy loads – limestone and granite blocks, as well as timber and other resources – close to and up onto the plateau. While a great volume and expanse of water might accumulate at the far, low end of a long lateral floodplain slope, like that of recent times (Figs. 11.7 and 11.10, both above), this body of water would be shallow and much lower with respect to the dockside tracks up onto the plateau. A Nile pressed against the west would dam any of it its own waters, and pyramid builders could have drawn this water into basins and canals that they had cut into the western riverbank, albeit requiring a level of effort such as they mustered to build the gigantic pyramids and causeways themselves. By building up a sufficient head of water at gateways through the western levee, here, behind the Ro-She Khufu, they could augment the 7 m hydraulic lift offered seasonally by the Nile inundation. If they dredged a canal basin to river depth all the way to the base of the plateau (Figs. 11.1–2 above), they could have reduced the height as well as the distance to which they would have to drag stone blocks after offloading to get them up onto the pyramid plateau.

Two Ways from Tura: She and Ro-She Khufu

Tallet found a pattern in Merer's journeys in that when he and his team came from and went to Tura North they stopped overnight in *R-š Ḫwfw* ('Entrance to the Basin of Khufu'), but when they came from or returned to Tura South they stopped over in the *Š Ḫwfw* ('Basin [or Lake] of Khufu'). That seems, at first, illogical: we would assume one would have to go through the entrance of a basin to get into that basin. As noted above, Tallet (2016:17–18) originally thought that the two terms *R-š Ḫwfw* and *Š Ḫwfw* served as alternate designations of the same place, but now he sees them as referring to distinct geographic entities, in part because they refer to stopovers in itineraries for the separate designations of Tura North and Tura South (Tallet 2017:52).

The Wadi el-Jarf Papyri contain what is now the oldest attestation of the toponym *Rꜣ-ꜣw*, the location of the fine white limestone quarries at Tura.[67] These extend south in a line to Maasara, and consist of more than 50 extraction points over 7 km (Tallet 2017:38, citing Klemm and Klemm 2008:51–5). Tallet sees this distance as far enough apart to have warranted two different water routes to Giza,[68] which are shown in his reconstruction (Tallet 2017: figs. 22–3). From Tura North, Merer and his phyle fared downstream on an eastern channel. This was the shorter route, a two-day round trip, including loading and offloading stone. They crossed the valley to the east of, and slightly northeast of, the Giza Plateau, to arrive just outside the gateway between the places now occupied by Nazlet el-Sissi and Nazlet el-Batran East. This was the entrance to the great bite that Khufu's forces took out of any western river levee and out of the low desert for water transport infrastructure. From here they could proceed – 'sail' (*sqdwt*) – to the end of the central canal basin in front of the quarry where the next generation would complete the Sphinx, Sphinx Temple and the Khafre Valley Temple. From there they could proceed on the natural slope right up to the southeast corner of the Khufu pyramid project (Figs. 11.1–2 and 11.23–4, all above). Alternatively, they could turn right (north) and go into the enclosed marina fronting the Khufu Valley Temple (Figs. 11.18–19 above), at the foot of a much longer and steeper ascent up the causeway embankment.[69]

From Tura South, in contrast, Merer and his men would cross the valley at the latitude of Abusir, then take the western channel, roughly along the course of the Libeini, although at the latitude of Zawiyet el-Aryan they would keep farther west (Fig. 11.12 above). Perhaps they took the westernmost of four or five braided channels that stretch from Shubramant 4.6 km to the northwest (Lehner 2009: pl. 14; see also Fig. 11.12 here), so that when they arrived just above Giza, due east of the Heit el-Ghurab Dynasty IV settlement site, they were in another, perhaps smaller channel, that led to a broad area east and southeast of AERA's exposure of Heit el-Ghurab. Tallet (2017: fig. 22) suggests we should visualise the *Š Ḫwfw* as being here. Coming onto this 'Lake of Khufu' during the season of cargo transport – inundation – (Cooper 2014:105, 130–1), Merer and his *s3* avoided passing through the eastern gateway – the *R-š Ḫwfw* – of the central canal basin. And here, they might spend the night, on the shores of the wharf-like peninsula of the Heit el-Ghurab (Lehner 2016:118–19). Yet the team may have been far enough from the access up onto the plateau to require yet another day of sailing to reach the offloading place around the bend of that peninsula.

Was There a Lake South and East of Heit el-Ghurab?

Can we see evidence of 'Lake Khufu' (*Š Ḫwfw*) east and southeast of Heit el-Ghurab? For modelling water transport infrastructure at Giza, I took as evidence modern surface contours as vestiges of ancient features, ancient structures and settlement encountered through excavation, deep drilling (AMBRIC) that retrieved and logged sediments, and the geomorphology of the Nile, its levees and floodplain in recent times.

If a Nile channel followed the course of the old Libeini Canal, it would flow into my proposed central canal basin from a slight northeast to southwest angle, because of its bend and because it shares the counter-clockwise orientation common to Dynasty IV structures at Giza (Dash 2012), except for the pyramids, their temples and their mastaba cemeteries. This bend delivered water straight into the mouth of the central basin canal, from the Nile channel to the Sphinx, 2.5 km west.

The Heit el-Ghurab Spur – How Far East?

To review, Heit el-Ghurab extended along the southern flank of the long delivery zone where I placed the central canal basin. The Dynasty IV Egyptians built Heit el-Ghurab as a peninsular institution on a spur of the low desert (Lehner 2002:66–7; 2016:118–19). When we excavate deeper than the bottom of the settlement, we find low desert sand near 15 m asl. In recent centuries, broad bays bounded Heit el-Ghurab north and south.

The bay north of the site is the mouth of the central wadi. As I described above, excavation has revealed that the Dynasty IV builders massively quarried and dredged this bay.[70] The bay south of the site, which is also the mouth of a wadi (Lehner 1985a: 113, 116, fig. 3A, number A15), bounded the 'Southern Field' of the Giza Necropolis (Fig. 11.2 above). This bay appears in older photographs as the lower floodplain reaching farther west, while to the north of it the sheet of low desert sand reaches out east from the Maadi Formation escarpment (Lehner 2009:122–3, fig. 49).

It is possible that the pyramid builders created the northern flank and more easterly part of the Heit el-Ghurab peninsula by dumping wadi sand and gravel that they had dredged from the mouth of the central wadi to make the canal basin. This is indicated by the deep AMBRIC drill core drillings (B256 and B262) that show only, or mostly, coarse sand and fine gravel below the settlement horizon (Figs. 11.14 and 11.23–5, all above).

For example, B256, drilled just north of Heit el-Ghurab, shows sand and gravel nearly solid under Old Kingdom settlement material (pottery and granite fragments) in clay and sand between elevation 16.02 and 14.17 m asl (AMBRIC 1989:B124) – roughly the range of the Heit el-Ghurab site (Fig. 11.25). B262, slightly farther east, showed pottery between 16.73 and 13.78 m asl, again, within the elevation range of Heit el-Ghurab (AMBRIC 1989:B137). Below these settlement traces, both cores penetrated only coarse sand and fine gravel. B263, along the eastern edge of our exposure of the HeG showed all sand, with pottery between 13.55 to 11.55 m asl, except for a 43

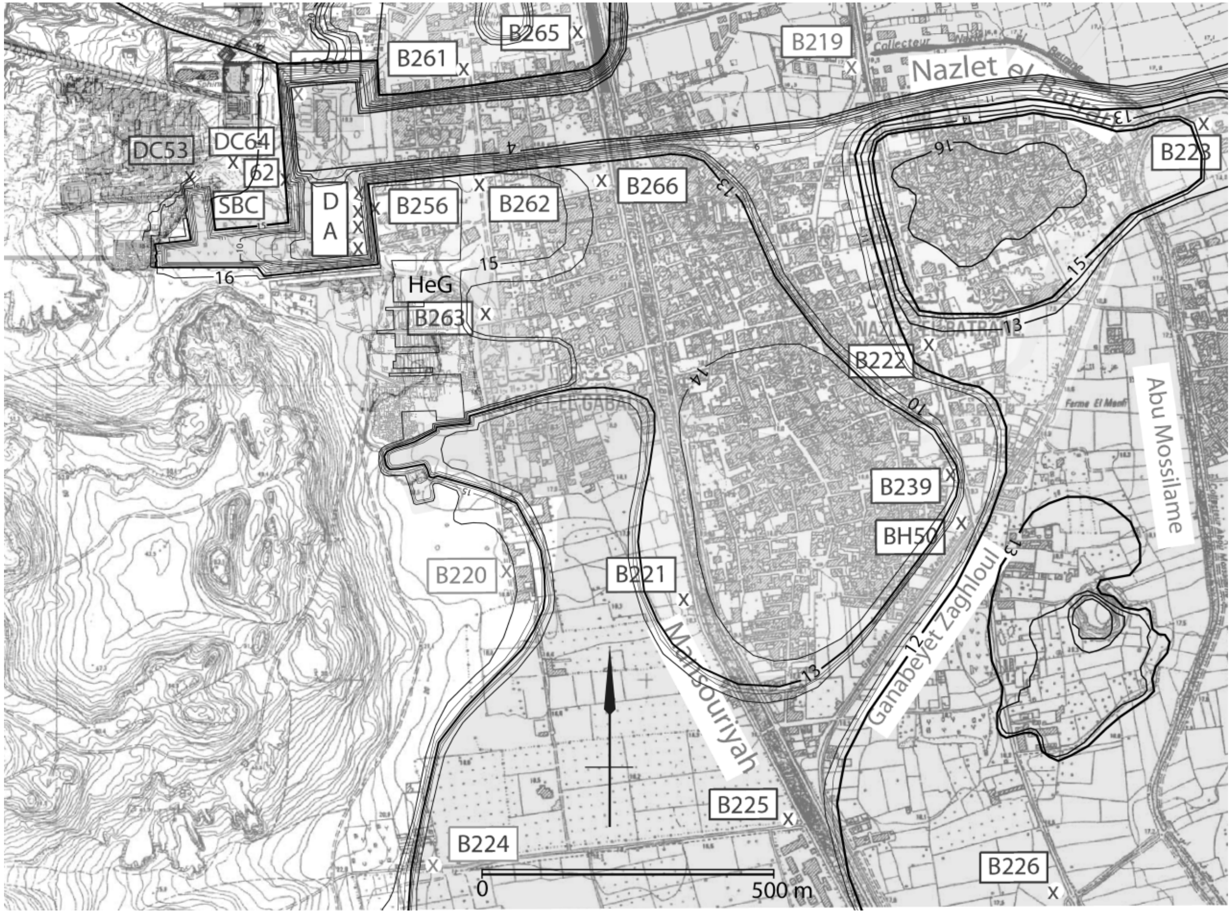

Figure 11.25 Contour lines of the reconstructed water transport structures overlaid on the 1977 MHR map of the Maadi Formation escarpment, low desert and floodplain in the southern zone of the Giza Pyramids. The Heit el-Ghurab (HeG) site, superimposed, extended farther east and south in the area covered by Kafret Gebel.

cm thick silt layer between 10.55 to 10.12 m asl (AMBRIC 1989:B139), conceivably the bottom of an ephemeral shallow channel or catchment 1.5–2 m below the level of the Dynasty IV floodplain (Fig. 11.25). After the building of the dams at Aswan, Nazlet el-Batran sprawled out onto the floodplain (Figs. 11.14 and 11.22, both above) from higher ground under the original settlement. This original site had risen with the floodplain ever since the Dynasty IV pyramid builders dredged the wadi mouth to create the central canal basin and dumped the desert sand and gravel to the south to raise and extend the low desert spur under Heit el-Ghurab.

These three core profiles near Heit el-Ghurab (B256, B262 and B266) are also discussed by Butzer *et al.* (2013:3350). They suggest that the deep sand and gravel in these cores, almost devoid of silt and clay, might be taken to represent fill washed by wadi flooding into an incised channel, or a Khafre harbour. However, they note the profiles are too far south for either explanation, observing: 'There is no geometric perimeter of spoil heaps like those of the verified NK harbor at Malqata (Luxor).' Their reference here is to Kemp and O'Connor (1974), who record that the orderly mounds at Malqata rise 14 m above the surrounding surface.[71]

The Birket Habu basin at Malqata, at 1 × 2.4 km, is an order of magnitude bigger than any basin we can reconstruct here. Also, any Old Kingdom basins at Giza (*ca.* 2500 BCE) will have suffered some 1200 years or so more erosion and annual inundation cycles than the gigantic basin of Amenhotep III at Luxor (*ca.* 1370 BCE). And like the makers of Birket Habu, who placed the Malqata terrace at the northern corner (Kemp and O'Connor 1974:116–18), the builders of the Giza basins may have spread the excavated soil to make raised terraces flanking the basin edges. Finally, the Giza builders would have used any Nile alluvium for the mudbrick to build nearby settlements, including Heit el-Ghurab.[72]

Here, at Giza, the terrace (the pile) was to the south of the central canal basin (the hole). This sprawling high ground, like the mounds of Nazlet el-Sissi and Nazlet el-Batran East, remains as a vestige of large-scale Dynasty IV landscaping. But how far east did it extend? We traced the Dynasty IV Heit el-Ghurab footprint for 150 m east of the eastern end of the Wall of the Crow. The architecture probably extended at least another 100 m east, as well as south, under modern Kafret Gebel, west of the Mansouriyah Canal.

In the 2002 'Wall Trench' we found that the 'Eastern Town' along the eastern rim of Heit el-Ghurab (Lehner 2002:65–7, fig. 18) continues east on the desert spur, under the modern town. This part of the settlement may extend all the way to the Mansouriyah Canal, about 425 m beyond the end of the Wall of the Crow. Hawass (1996:56–9) reports a continuous horizon of Old Kingdom settlement seen in the late 1980s AMBRIC trench for a large waste water pipe along the Mansouriyah Canal (see also Hawass and Senussi [El-Sanussi] 2008:127). That settlement horizon picked up 50 m south of the basalt pavement marking the Khufu Valley Temple location and continued at least 1.8 km to the south. The settlement layers thickened from north to south, where the upper of two phases contained Dynasty V pottery. I have suggested that during Dynasty V this extension of the Heit el-Ghurab settlement, known as the *ṯnj*, 'bank settlement', lived on as a simpler docking place alongside a western Nile channel that followed the course of the Mansouriyah (Lehner 2016:143).

It should be noted that if Merer and his men docked overnight here, at the supposed eastern extension of the Heit el-Ghurab site at about the line of the Mansouriyah Canal, the next day they would have had to travel 0.5 km north, and then another 0.5 km west, around the bend of Heit el-Ghurab to get to the offloading point at the western end of the central canal basin.

Another More Westerly Channel?

Tallet's hypothetical She Khufu south and east of Heit el-Ghurab must have been watered by a channel that departed from the course of the Libeini and entered southern Giza farther west than the Libeini and its bend (Tallet 2017: figs. 22–3). His drawing suggests this 'Lake of Khufu' expands from such a channel into a broad catchment basin. Perhaps Merer's team took the most westerly of the braided channels where the single linear trough of the Libeini adjacent to Saqqara breaks up opposite Zawiyet el-Aryan. Merer's team may have then continued north to Giza on a track roughly parallel to the Libeini until the point where the braided channels come together just above Giza (Fig. 11.12 above). This track corresponds to the line of the Mansouriyah Canal, about 425 m beyond the end of the Wall of the Crow. The Mansouriyah runs west of, and parallel to, the Libeini. A fourth-to-third-millennium BCE Nile channel on this course, west of the Libeini, has been hypothesised (Lehner *et al.* 2009:106–10).

Bunbury *et al.* (2009: pls. 38–9) have pointed to subtle, linear ridges in the contemporary topography as possible vestiges of river levees moving progressively east in this zone (see also Lutley and Bunbury 2008). These ridges run between the low desert edge and the Mansouriyah, and from the Mansouriyah to the Libeini. The easternmost one runs along the two canals on a line to the northeast about 1.68 km from Heit el-Ghurab, while the middle and westernmost ridges run respectively 776 and 86 m to the east of the limit of our exposure of the settlement along a modern road. The latter is not far from our 1998 excavation in LNE (Lehner *et al.* 2009b:120–2)[73] and it is about where the sand sheet of the low desert meets the floodplain in Reisner's (1942: pls. 5a, 6) photographs taken between 1913 and 1932. Butzer (2016:74) is right that good stretches of these alleged former levees correspond to modern road embankments, including that along the Marioutiyah. However, we do see linear, levee-like, strips of higher ground within this zone in photographs taken before the modern roads or canals were created. One photograph, taken in 1914 from the top of the Khufu Pyramid, shows western, linear, sand ridges coming from the south in the valley and low desert southeast of the Giza Plateau (Fig. 11.26). The western ridge passes not far to the east of the end of the Wall of the Crow, and we see another sand ridge farther east – possibly the eastern levee of the same relic channel – running from the south to the higher ground of Nazlet el-Batran West.

A photograph taken nearly two decades later, just after 1932 (Fig. 11.27),[74] shows the Mansouriyah Canal, or a small precursor, on the track of the eastern of these two ridges. Engineers might have dredged the canal in a trough that remained from an older channel running from the southeast to the western side of Nazlet el-Batran.

The question – as with the subtle depressions east of the Khufu and Khafre valley temples, or the course of the Libeini – is whether any of these features could remain from the in-filling and raising of the floodplain by centuries of Nile alleviation, albeit a bit less than the five or six metres of younger sediments that Butzer (2016:74)

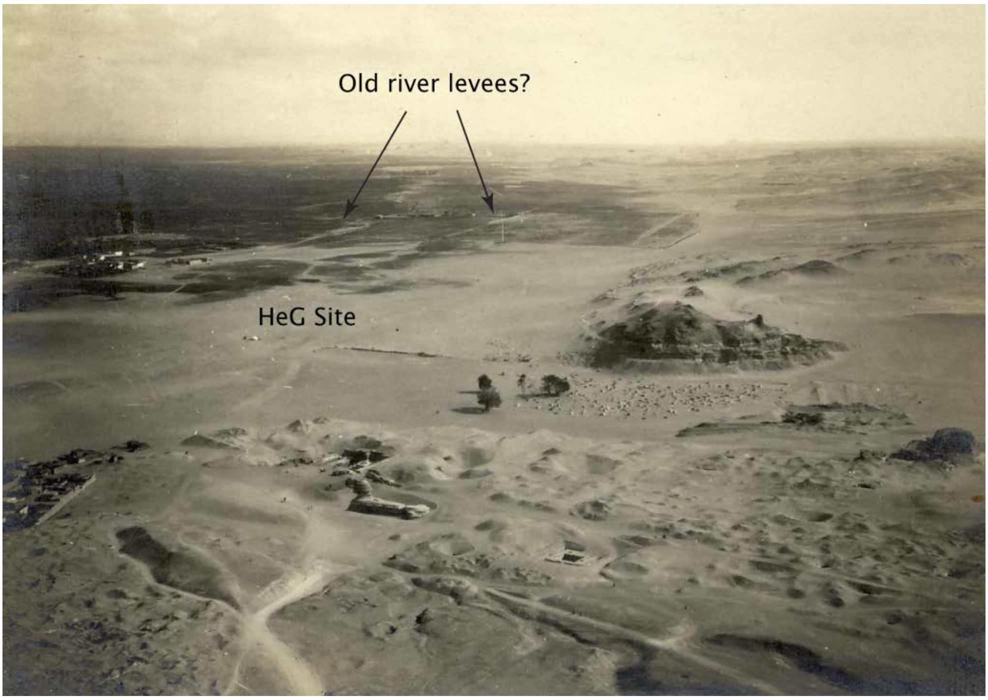

Figure 11.26 1914 photograph from the top of the Khufu Pyramid, with view to the southeast of the Giza Plateau. Linear, levee-like sand features may correspond to the westernmost of levees cited by Bunbury *et al.* (2009). The floodplain reached west in an embayment south of Heit el-Ghurab (HeG).

suggested, and rather more like 3 m over the Dynasty IV levees and 5 m over the Dynasty IV floodplain (17.50 m asl for the modern floodplain minus 14.50–15.00 m asl for hypothetical Dynasty IV Nile branch levees and minus 12.00–12.50 m asl for the inferred Dynasty IV floodplain).

If the most westerly channel had continued north across the opening of the central wadi, as it possibly did before the drastic interventions of the pyramid builders, starting with Khufu, it would have passed right in front of the Khufu Valley Temple, which would correspond to what Butzer *et al.* (2013:3345, fig. 2C) suggest for an Old Kingdom river channel. This is also the path of the drainage channel I propose running of the north end of the Khufu Marina (Figs. 11.1 and 11.15, both above). AMBRIC cores B207 and B209 for this area show solid, very deep clay and silt on this track, down to 1.51 and 3.57 m asl, possibly the fill of an old, pre-Khufu channel. The 'wings' of high ground north and south the Khufu Valley Temple location (Figs. 11.14, 11.20 and 11.22, all above) could remain from a western Nile levee pressed against the west. The horizon of ancient settlement reported from the AMBRIC trench along the western side of the Mansouriyah Canal (Hawass 1996:56–9) runs south for 1.8 km close along this line. We see this high ground and possible former western levee in the oldest aerial photo of Giza, which Edouard Spelterini (1928:88) took on 21 November 1904 from a balloon from just above Nazlet el-Sissi and Nazlet el-Batran East.

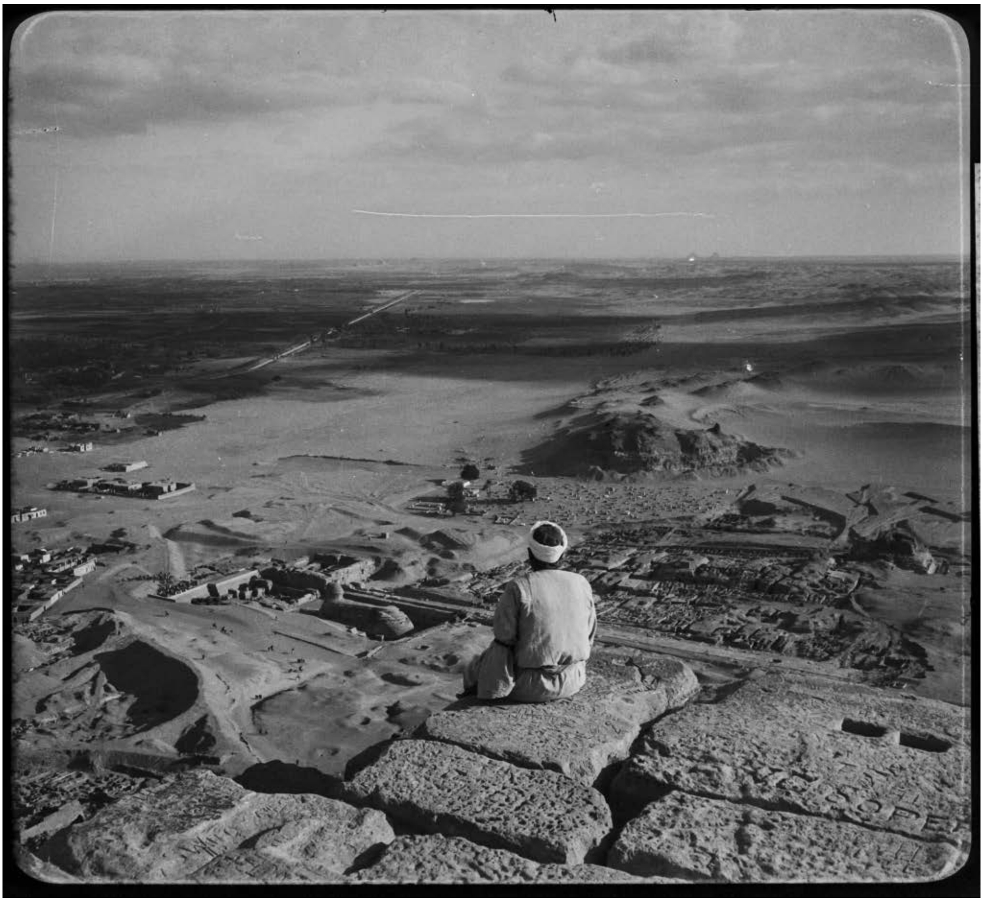

Figure 11.27 One of a set of four stereo-negatives of Giza, dated 1928 but taken soon after 1932 (as shown by the presence of excavation works). This view of the valley to the southeast from the top of the Great Pyramid shows the Mansouriyah Canal, or a small precursor, on the track of a possible older channel running from the southeast to the western side of Nazlet el-Batran West (image purchased by author from private seller in Vienna).

The *Š Ḫwfw* Catchment and the 'Beak of Lake Khufu'

Merer's journal indicates his team stopped at the *Š Ḫwfw* and not the *R-š Ḫwfw* when coming from Tura South, and Tallet (2017: fig. 22) places this location south and east of Heit el-Ghurab. I do not extend my modelling attempt much farther south than the wadi bounding the Southern Field (*PM* III/1 294–7, plan III) of the Giza Necropolis, which is the extent of the AMBRIC (1989) drilling logs available to me. Here, an old channel on the track of the Mansouriyah Canal would have fed into a broad catchment basin, somewhat along the lines that Tallet proposes for the *Š Ḫwfw*. On the west, this catchment becomes something of a *cul de sac*, but evidence suggests an outlet on the eastern side gave exit, opening from around the Heit el-Ghurab high ground directly into the central canal basin, without going through the Nazlet el-Sissi–Natzlet El-Bartan East gateway, the proposed *R-š Ḫwfw*.

I wrote (see above) of those core drillings (B256 and B262) at the north and east ends of AERA's exposure of Heit el-Ghurab. The logs of these drillings show, under settlement traces at the same elevation as the HeG, almost entirely sand and gravel as deep as -1.73 and -2.57 m asl, which suggests a sand and gravel terrace that projected east above the Nile floods (fig. 11.25). Again, the pyramid builders may have augmented the natural low desert to create this terrace.

To the south and slightly east of this area, B263 likewise showed all sand, with pottery between 13.55 and 11.55 m asl, except for a lens of silt, 43 cm thick, between 10.55 and 10.12 m asl, conceivably the bottom of a channel or catchment 1.5– 2 m below the flood plain (Figs. 11.25 above and 11.28). The uniform, deep and consistent sand and fine gravel in core drillings B256, B262 and B263 offer no suggestion of a basin and catchment for Nile floodwaters. Rather, the drilling points, again, to the natural, low desert spur and terrace, augmented perhaps by the pyramid builders for founding the settlement and infrastructure of Heit el-Ghurab.

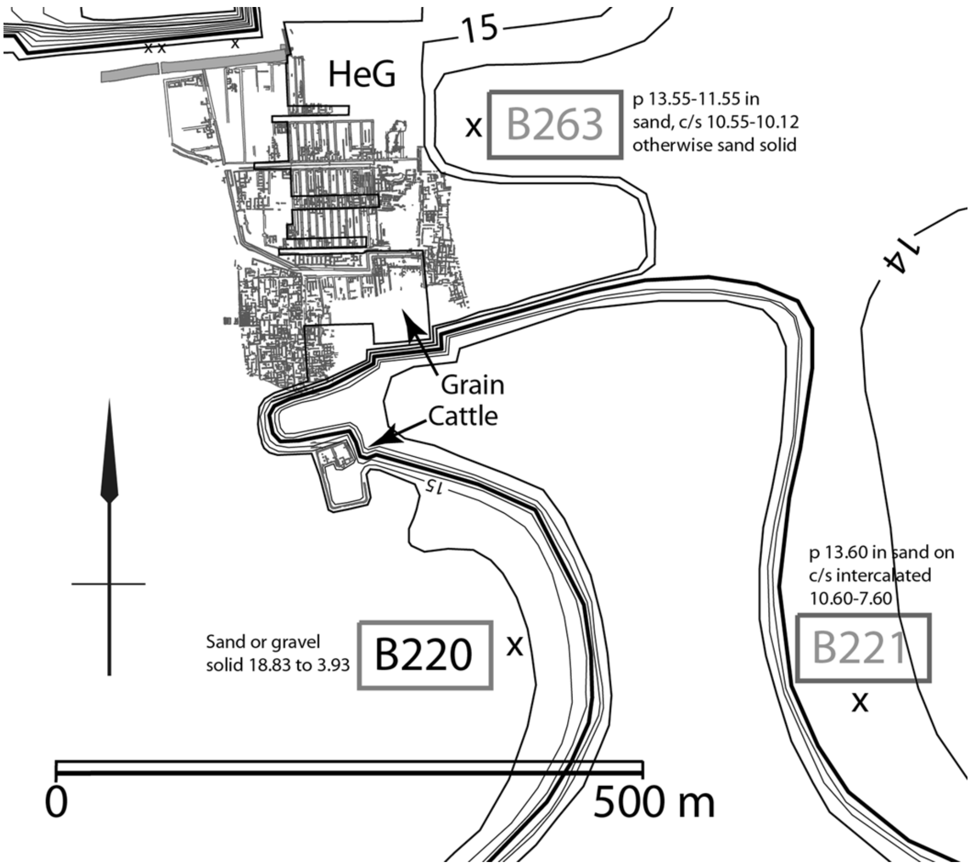

Figure 11.28 Contoured reconstruction of Dynasty IV topography south and east of the Heit el-Ghurab (HeG) Dynasty IV settlement site. Numbers in rectangles are AMBRIC core drillings. Notes summarise logs of AMBRIC core drillings below 16 m asl: p = pottery; c/s = clay/silt; c/s intercalated = clay/silt interleaved with sand. We hypothesise that inhabitants delivered grain from the depression (Lagoon 1) north into the silos in the Royal Administrative Building, and cattle south into the Standing Wall Island (SWI) corral and compound.

B221, 650 m farther south (Figs. 11.25 and 11.28, both above), also shows pottery in sand between 15.22 and 13.60 m asl. The pottery, an indication of settlement, is here slightly lower than the settlement horizon of the Heit el-Ghurab site. B221 hit two bands of silty clay between 10.60 and 7.60 m asl, with a sand layer in between. I take this clay/silt layer as sediments from Nile water filling a channel or catchment basin 1.5–2 m lower than the floodplain, which I estimate around 12 m asl. However, I draw the edges of the catchment west of B221 (Fig. 11.28) on the rule that pottery in the range of 11–15 m asl indicates the Dynasty IV living floor, at least during the dry season.

Only 320 m to the west, B220 shows only solid sand and gravel, the low desert beyond the floodplain. Between B220 and B221, I place a shallow channel, 3–4 m deep, which would fill from the south during flood season. I model this shallow channel here for the reason that AERA excavations revealed a deep, sand-filled depression farther north, in the triangular area between the three AMBRIC boreholes B263, B221 and B220 (Figs. 11.25 and 11.28, both above).

My co-investigators and I call this sand-filled depression 'Lagoon 1' (Lehner *et al.* 2009a:39; see fig. 22 here). We exposed the northern edge of it east of a modern soccer field that covers this area of the site. Evidence indicates that this lagoon featured in the Dynasty IV topography, as opposed being cut by forces of erosion like the downward slope and loss of Old Kingdom settlement along the northeast of Heit el-Ghurab (Lehner 2015a:90). Lagoon 1 separates the 'Western Town' at the southwestern end of Heit el-Ghurab from another patch of settlement 50 m south, which we call Standing Wall Island because we found fieldstone walls standing up to 1 m high. These walls frame two enclosures that open onto another sand-filled depression, Lagoon 2, which is surrounded by another fieldstone wall. In 2011 we found that the perimeter fieldstone wall curves around Lagoon 2 in a paper-clip pattern, with a corridor opening on the northeast. We hypothesised that this broad enclosure served as a cattle corral (Redding 2011). Excavations revealed that the eastern enclosure, ES2, in the northeastern corner of this compound was a house, no doubt for the administrator. We hypothesise that at least four other houses north of Lagoon 1 also served as official residences, 'gathered round the delivery bay, like custom houses at the ends of harbors' (Lehner 2015a:90). Sealings from 'Pottery Mound', a dump between Houses 1 and 2, contained sealings bearing the names Khafre and Menkaure and some of the highest-ranking scribal titles of their time (Nolan 2010).

My further hypothesis is that that people delivered material through this draw (Fig. 11.28), on foot or donkey from late winter through early summer, and on small boats during the late summert o early winter when the Nile flood filled it with water at least three or four metres deep. When that happened, Lagoon 1 would function as a put-in bay for small craft. Carbohydrates, in the form of grain, went to the north into the multiple granary silos in the so-called Royal Administrative Building, while protein, in the form of cattle, went to the south through the paper-clip corridor opening onto the Lagoon 2 corral. As a 'put-in' harbour, the Lagoon 1 'back bay' (Lehner 2014b:21–3) makes sense for a cattle-processing centre to the south – Standing Wall Island – and a grain-processing centre to the north, the Royal Administrative Building enclosure with its court of large grain silos (Lehner 2015a:91, fig. 12). As such, Lagoon 1 would have been an important stop.

I contoured a catchment basin that avoided the positions of drill cores that indicated pottery (= settlement) between 15 to 11 m asl. I connected this basin to the Lagoon

1 depression; and drew its northern edge to allow that the land that hosted the Heit el-Ghurab settlement extend farther east than our exposure of it on a peninsula of sand and fine gravel, as indicated in borings B256, 262 and 263. By accounting for these features, and the westward projection of Lagoon 1, the northern end of the basin looks like the head of a bird in plan view, with Lagoon 1 as its beak. I mention this odd shape that I derived for the put-in bay as a coincidence with one of the terms for a feature of *Š Ḫwfw* mentioned in Merer's journal. Section BX, comprised of six fragments of the lower part of Papyrus B, documents another ten-day stint of activity of Merer's phyle (Tallet 2017:68–71, pls. XVIII–XX). On Day 1b the team fares downstream and arrives at the *spt? sẖꜣt nt Š-Ḫwfw,* which Tallet translates as 'la berge de la Pointe de Ché Khoufou' ('bank on the Point of the Basin [or Lake] of Khufu'). On Day 2a they proceed to Akhet Khufu – the Great Pyramid – and then (Day 2b) to the *R-š Ḫwfw*. On Day 3a they are at Tura North.

Tallet writes that *sẖꜣt* is something of a *hapax*. As a topographic and nautical feature (a bank), the determinative is the sign of a leg of beef, but in two other contexts in these papyri, the word is determined with the ideogram of grains of sand. Tallet (2017:95–6, fig. 21) cites the term *sẖꜣt* as a label, 'spout', in a scene of manufacturing a metallic vase from the Unas pyramid causeway at Saqqara (Hassan 1938: pl. 96; Hannig 2003:1196). He suggests that in the context of Nile navigation in Merer's journal the term should refer to a 'structure allongée, peut-être légèrement recourbée à son extrémité. Il pourrait s'agir d'une digue, d'un cap ou d'une pointe – si l'on pense à une structure pleine – ou encore d'un canal aménagé, si l'on retient le sens de conduction de l'eau qui est aussi propre à l'objet ainsi désigné' (Tallet 2017:70). This could match my reconstruction of the dyke with a rounded end under the Zaghloul Street Wall (Figs. 11.1 and 11.18–19, all above), although that reconstruction is a bit arbitrary. However, for the *sẖꜣt* of Lake Khufu, we should think of a feature southeast of the Giza Plateau. It is also worth mentioning that the term *sẖꜣt* occurs with the sand-grains determinative on a fragment that possibly derives from another document (Papyrus C?). Here it is the object of a verb: *[ḫ]ws sẖꜣt / sẖꜣwt*, 'tamping-' or 'compacting the point(s)'. Tallet (2017:80) points out that the verb *ḫwsj* is used regularly in papyrus C, which relates to work in the Delta on what might have been a port.

As for any other '*structure allongée*' in this area to which the papyri might refer, the gigantic Wall of the Crow (the Heit el-Ghurab) is certainly dyke-like, as wide on the base (10 m) as it is tall and encumbered on both sides by limestone debris 2–3 m high (Lehner and Tavares 2010:176–7). We know that builders created this wall after a second, younger phase, of Gallery Set I, since the end of it abuts the plastered western face of the gallery set's western wall (Lehner 2002:51; Lehner *et al.* 2009a:23–4). As such, the Wall of the Crow probably dates to Khafre or later, like most of what we have mapped of Heit el-Ghurab. However, in trenches north and south of the Wall of the Crow, we found markedly different layers that the builders cut through when they dug its foundation trench. The difference in the surfaces that predated the Wall of the Crow, north and south, suggest that it replaced some earlier barrier (Lehner and Tavares 2010:178). Could this barrier have been designated *sẖꜣt nt Š-Ḫwfw*?

On the other hand, is it possible that Lagoon 1, with its bird beak-like outline, as I reconstructed it, is the referent for the *sẖꜣt* as '"bec", cap, pointe, avancée dans l'eau'

(Tallet 2017:139)? Our findings certainly suggest that the 'beak' of Lagoon 1 served as a place of administrative control and provisioning. So far, all material from our excavations of the houses at the head of the bay and of the Standing Wall Island compound – pottery, and sealings of Khafre and Menkaure – date from the mid- to late Dynasty IV, Khafre to Menkuaure; there are no sealings of Khufu. However, in the Royal Administrative Building compound, to the north of the bay, we found a significant older phase (Lehner and Sadarangani 2007:67–72) of a different architectural arrangement. At some point, probably under Khafre, the royal house demolished the older phase, down to knee-to-ankle level, and rebuilt the Royal Administrative Building above it. Builders also expanded the massive outer fieldstone walls of the structure by building over older domestic structures of the 'Eastern Town'.

As further evidence that suggests Lagoon 1 featured in the Dynasty IV topography, a deep probe along the eastern wall of the Royal Administrative Building, as well as in pits in its interior, revealed interleaved layers of clay and sand that the Dynasty IV settlement builders dumped into the lagoon in order to raise the surface and extend the peninsular terrace before building the walls (Lehner 2002:67).

In sum, the *sẖꜣt nt Š-Ḫwfw* appears to be a stop where the team spends the night on the way to the Pyramid (fragment B53), perhaps coming from the south. The *sẖꜣt* has a bank (*spt*), artificially built, at least partially; thus Merer and his team arrive at the 'shore' or 'bank' of the Beak of Lake Khufu. Is this Lagoon 1, a 'put-in' bay extending off a larger basin?

Š-Ḫwfw – A Seasonal Lake?

Before the dams at Aswan, when the Nile still flooded its valley through Egypt, a basin (*ḥod* in Arabic, *š* in Egyptian) was a basin whether filled with water during inundation, or dry and cultivated during low Nile. Perimeter banks could be used for accounting, craft and industry all year round. Basins great and small were named. A *š* could be a lake, a tract of land and serve as a royal precinct. Traces in the 1977 topography and in the deep AMBRIC core logs indicate that the broad catchment south and east of Heit el-Ghurab, where Tallet (2017: fig. 22) would place the *š* of Khufu, might have been nearly dry during low Nile.

According to my most recent modelling, the broad catchment southeast of Heit el-Ghurab ends in the *cul de sac* of Lagoon 1. We do not know the bottom of Lagoon 1, and so far we have found no silt or clay under the clean sand that fills this depression.

I cannot see any good evidence in the AMBRIC boreholes of an outlet from Lagoon 1 north into the central canal basin. This outlet would have to pass through the HeG site or close along the eastern limit of AERA's exposure of Heit el-Ghurab. B263, across the modern road from the northeast corner of the settlement (Fig. 11.28 above), shows clay 43 cm thick between 10.55 and 10.12 m asl, which could be Nile sediments in an early seasonal or ephemeral channel about 2 m below a floodplain level of 12.00–12.50 m asl. Above this clay, B263 showed pottery, perhaps indicating an extension of the Heit el-Ghurab settlement, at 13.55–11.55 m asl (more than 1 m lower than Heit el-Ghurab). Immediately south of B263, we know the 'Eastern Town' extends east, beyond the AERA exposure, possibly as far as the Mansouriyah Canal.

The AMBRIC (1989) cores available to me extend only 500–700 m south of the Lagoon 1 inlet, about as far as the wadi bounding the Southern Field (*PM* III/1 294–7, plan III) of the Giza Necropolis (see Fig. 11.2 above). Three boreholes along this southern limit show what might be a silt-filled basin deeper than the Dynasty IV floodplain. B224 on the far west (Fig. 11.25, above), where the sand filling the southern wadi meets the cultivation of 1977, shows clay between 10.40 and 9.22 m asl, with sand above and below. With a floodplain around 12.00 m asl in my model, the bottom of the clay could mark the bottom of a basin, 2.78 m lower than the floodplain, in which Nile floods deposited clay, 1.6 m thick, at its western edge.

To the east, B225 shows clay between 14.67 and 13.65 m asl, which is too high to be coherent evidence for Dynasty IV basin land and floodplain. However, it was probably in the Old Kingdom that Nile flooding left the deeper clay and silt in this same drill core between 11.52 and 7.02 m asl to 4.5 m thick. If this clay and silt represent the same deposit as the deep clay in B224, the fill thickens in a basin that deepens to the east (Fig. 11.25 above). It should be noted that B225 and B221 to the north are both located along the western side of the Mansouriyah Canal. Higher sand and silt layers in these logs could represent the relic levee seen in the old photographs (Figs. 11.26–7, both above)

Further east in this same southern catchment area, B226 (Fig. 11.25 above), showed clay between 14.90 and 13.90 m asl, very similar to B225. Again, this clay is too high to represent the Dynasty IV floodplain. The Nile deposited this clay after the Old Kingdom, building up the floodplain. B226 showed sand between 13.90 and 11.52 m asl. From 11.52 m asl, close to my estimate for the level of the Dynasty IV floodplain, B226 showed clay and silt down to 7.02 m asl.

I note again that many of AMBRIC's cores north, south and east of the eastern base of the Giza Plateau show a boundary between clay and sand around 7 m asl, with no clay, only sand, from here to the bottom of the core drilling. Cores showing this boundary at 7 m asl surround the central zone of 'very deep clay', at 4 to 3 m asl. This 'very deep clay' is the 'overdeepened channel' of Butzer *et al.* (2013:3344). The base of the clay/silt at 7 m asl must mark the beginning of floodplain aggradation over Pleistocene sands and gravels. This boundary is found in several AMBRIC borings under settlement material that is very likely Old Kingdom, such as in those borings immediately north and south of Khufu's lower causeway (B257, B258, B259 and B264 – Figs. 11.18-19).

To return to the southern cores, the top of the deep clay in B225 (11.52 m asl), B226 (12.10 m asl) and in BH50 (11.99 m asl) is just about on my estimate of 12.00 m asl for the Dynasty IV floodplain. From this level down to the bottom of the clay horizon around 7 m asl, the clay and silt in these southern cores could mark floodplain aggradation that predates Dynasty IV. To the extent that the 7 m asl clay–sand boundary is natural – as opposed to the 'overlydeepened' boundary at 4 and 3 m asl or deeper – we cannot take it as the bottom of an artificial Dynasty IV catchment. Again, we should instead understand this boundary as the bottom of natural Nile silt deposition over the top of a Pleistocene bed of sand and fine gravel.

But we should also keep in mind evidence that the Dynasty IV Egyptians could and did intervene on very large scales in the wadi and floodplain of Giza. Aside from 'overlydeepening' the 'Khufu Marina' (*Š ꜣḫt Ḫwfw*), the central canal basin and the gateways around Nazlet el-Sissi (*R-š Ḫwfw*?), they built out the northern bank of

Lagoon 1 (*sḫ3t nt Š-Ḫwfw*?) and probably the southern bank of the central canal basin. If the catchment south of Nazlet el-Batran was *Š-Ḫwfw*, they could have deepened it for the important purposes evidenced in Merer's journal. The question is to what extent they used this basin in its natural form, and to what extent they dredged it. Based on traces in the 1977 surface and the lack of built features, this catchment is certainly less geometric than those east of the Khufu, Khafre and Menkaure valley temples. In this southern basin, to what extent is the clay and silt between roughly 12 and 7 m asl pre- or post- Dynasty IV?

In my most recent model, I contoured the area south of Lagoon 1 and Nazlet el-Batran as a deeper catchment on the west of the Mansouriyah Canal line, bottoming at 10 m asl, as a nod to the hypothesis that Lagoon 1 served as a 'put-in' bay, at least seasonally. However, this is arbitrary – we have no evidence yet for the depth or bottom sediments of Lagoon 1, and the bottom of this southern basin could have been somewhere between 7 and 12 m asl. To the east of the Mansouriyah and south of Nazlet el-Batran I contoured the surface as about 12 m asl, taking the top of the clay/silt – between 12 and 7 m asl in B225 and B226 – as being the Dynasty IV floodplain. This modelling would have closed off Lagoon 1 and the southern catchment from the central canal basin that leads to the low point of the Moqattam Formation, in the area east of the Sphinx, except for a channel that curves around the eastern side of the high ground under Nazlet el-Batran (Fig. 11.25 above). I see indications for this channel in modern surface contours and in the AMBRIC core drill logs.

As noted above, the village of Nazlet el-Batran was once separated into a main zone 'West' and a smaller 'East' housing zone (Fig. 11.29). This is due to a curved, channel-like catchment that ran through Nazlet el-Batran in the nineteenth and early twentieth centuries CE, and which defined the 'island' of what I designate as Nazlet el-Batran East. The original, more natural basin or stream discharge channel between Nazlet el-Batran East and West retained water as the flood receded, making for a picturesque view of the pyramids captured in many of the oldest photographs of the Giza Pyramids from the valley floor, handed down to us in stereoviews and postcards (Fig. 11.30).

My model includes a broad, shallow, discharge channel, 3–4 m deep, between the two parts of Nazlet el-Batran (Figs. 11.1 and 11.25, both above), to reflect the channel-like depression along here in recent centuries. The old canal, Ganabeyet Zaghloul (Figs. 11.14 and 11.25, both above), connected to this channel on the south along Zaghloul Street then split just below Nazlet el-Batran East. During flood, the old curved channel turned into a broad waterway around the west side of the mound of Nazlet el-Batran East, while Ganabeyet Zaghloul circumvented the settlement mound on the east. Modern canal diggers took advantage of ancient troughs. These waterways are now paved streets.

Tallet's (2017) fig. 22, which is meant to be an approximation, shows the *Š Ḫwfw* waters extending north between Heit el-Ghurab and Nazlet el-Batran East. However, aside from the curved catchment, I do not see strong evidence of a deep north–south channel until the Libeini-Marioutiyah canal trough on the west, which I expanded in the model (Fig. 11.1 above) to major Nile channel width (500 m).

I drew my broad, shallow, discharge channel (Fig. 11.31 below, the Nazlet el-Batran Channel), 3–4 m deep just where AMBRIC core drilling BH50 (Fig. 11.25 above) shows deep silt and clay between 11.99 and 7.62 m asl, very similar to B225 and B226 in

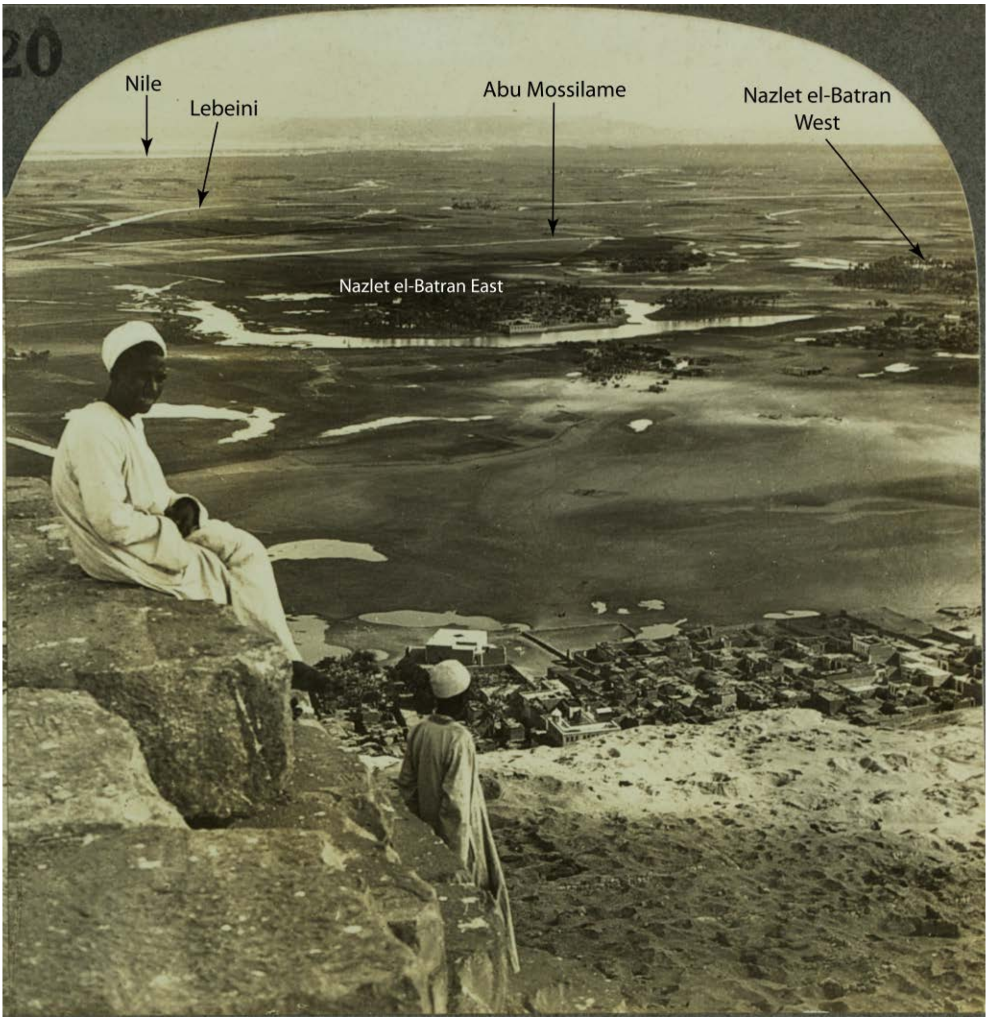

Figure 11.29 View from the summit of the Great Pyramid of Khufu to the southeast, showing Nazlet el-Batran East surrounded on the south, west and north by a curved catchment channel, and in the background the canals Abu Mossilame and Libeini, and, faintly in the far distance, the Nile on the eastern side of the floodplain (from a stereoview copyrighted by Underwood & Co., early twentieth century).

the southern catchment. A short distance north, B239 showed pottery in sand between 14.08 and 13.28 m asl, which I take as Old Kingdom settlement on the western flank of this channel. Below these deposits, B239 showed intercalated clay/silt and sand down to 10.63 m asl. This I take as undisturbed natural stratification resulting from wadi, wind (sand) and Nile (clay/silt) deposits. B222, to the north and on the east side of the channel, showed clay from 12.53 down to 10.58 m asl, with pottery at 11.98 m asl – very near the predicted Dynasty IV floodplain elevation (12 m asl). B222 showed all sand – the edge of the ancient mound under Nazlet el-Batran East – down to clay 23 cm thick at 5.63 m asl, which has to be pre-Old Kingdom.

Figure 11.30 Old postcard view to the northwest over the channel along the southern shore (right) of the curved channel basin around Nazlet el-Batran East.

The high ground with settlement inferred from cores B239 and B222 does not augur well for a broad, deep, water-filled basin existing here, southeast of Heit el-Ghurab, and between Heit el-Ghurab and Nazlet el-Bataan East. However, the spacing of these cores allows a channel between them under the curving path between Nazlet el-Batran East and West, with a bed at around elevation 10.60 m asl. I reconstructed my shallow channel 1.5–2 m lower than the flood plain, based on the bottom of the clay in these cores. Unfortunately, we have no other core logs to the north on the curving line of this channel. The next core to the north, B219, shows very deep, solid clay from 12.01 – the elevation of the Dynasty IV floodplain – down to 3.81 m asl. Here we are in the middle of the 'overdeepened channel' – the central canal basin. So, my shallow channel enters this basin at its upper southern edge.

This reconstruction, on the evidence of the AMBRIC cores and traces in the modern terrain, suggests that the Nazlet el-Batran side channel existed as an outlet and exit on the eastern side of the southern catchment, and that it flowed east of, and around, the high ground extending east-southeast of the Heit el-Ghurab. The side channel enters directly into the central canal basin, without going through the Nazlet el-Sissi–Nazlet el-Batran East gateway, the proposed Ro-She Khufu. Cargo boats could only pass through the Nazlet el-Batran side channel during the inundation.

During a flood peak of 13.5–14 m asl (Fig. 11.32), the mounded settlements I reconstruct under Nazlet el-Batran and Nazlet el-Sissi, at around 15 m asl, would remain above water, as would the perimeter around the 'Khufu Marina' – or the She Akhet Khufu – just to the right (north) inside this entryway. To the left, south, the ground I have reconstructed east of the Heit el-Ghurab as slightly higher than the basin lands,

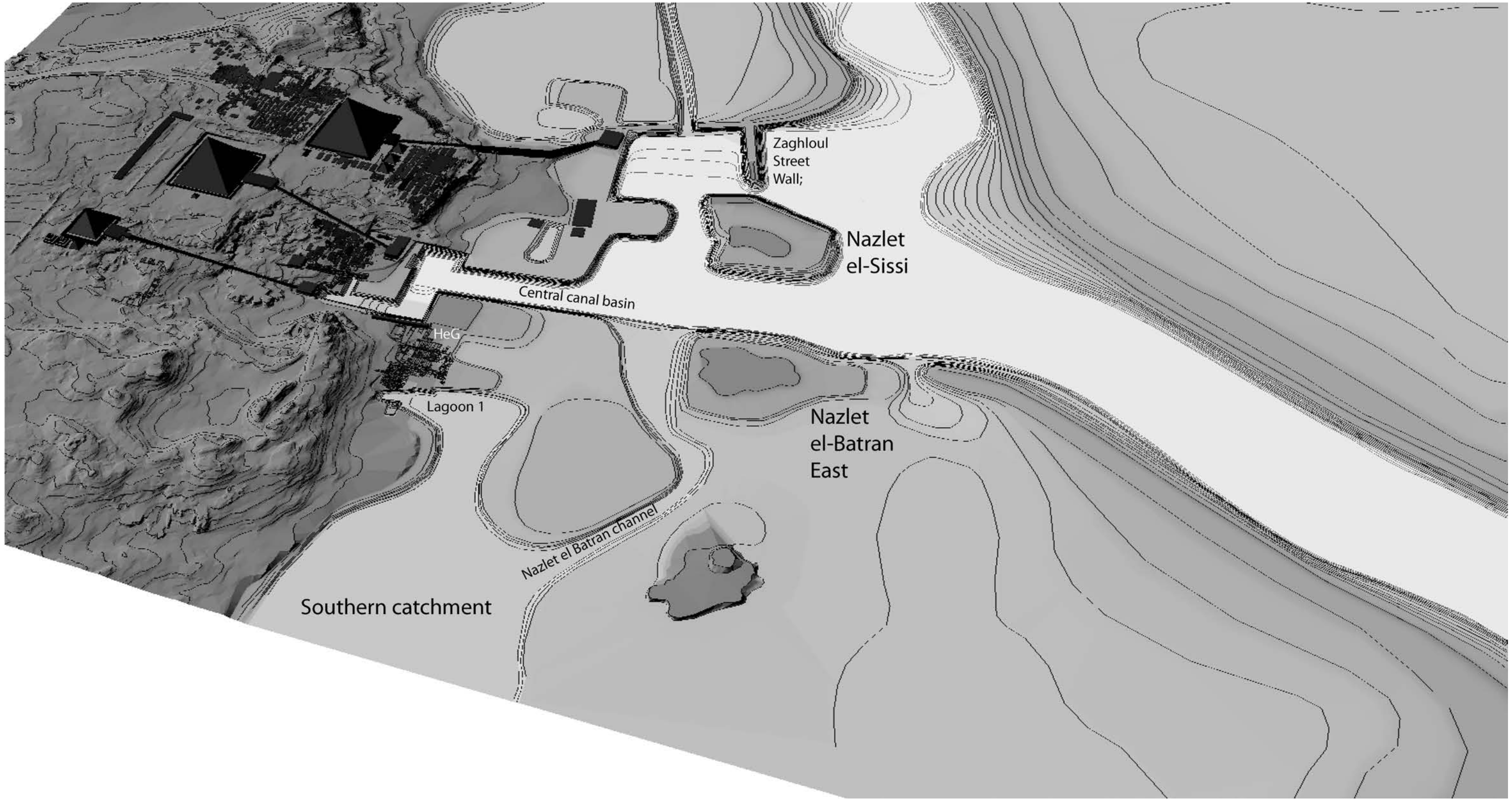

Figure 11.31 Reconstructed Dynasty IV floodplain and water transport infrastructure at low water, with a water level near 7 m asl. View from the southeast to the northwest (graphic by Rebekah Miracle from AERA GIS).

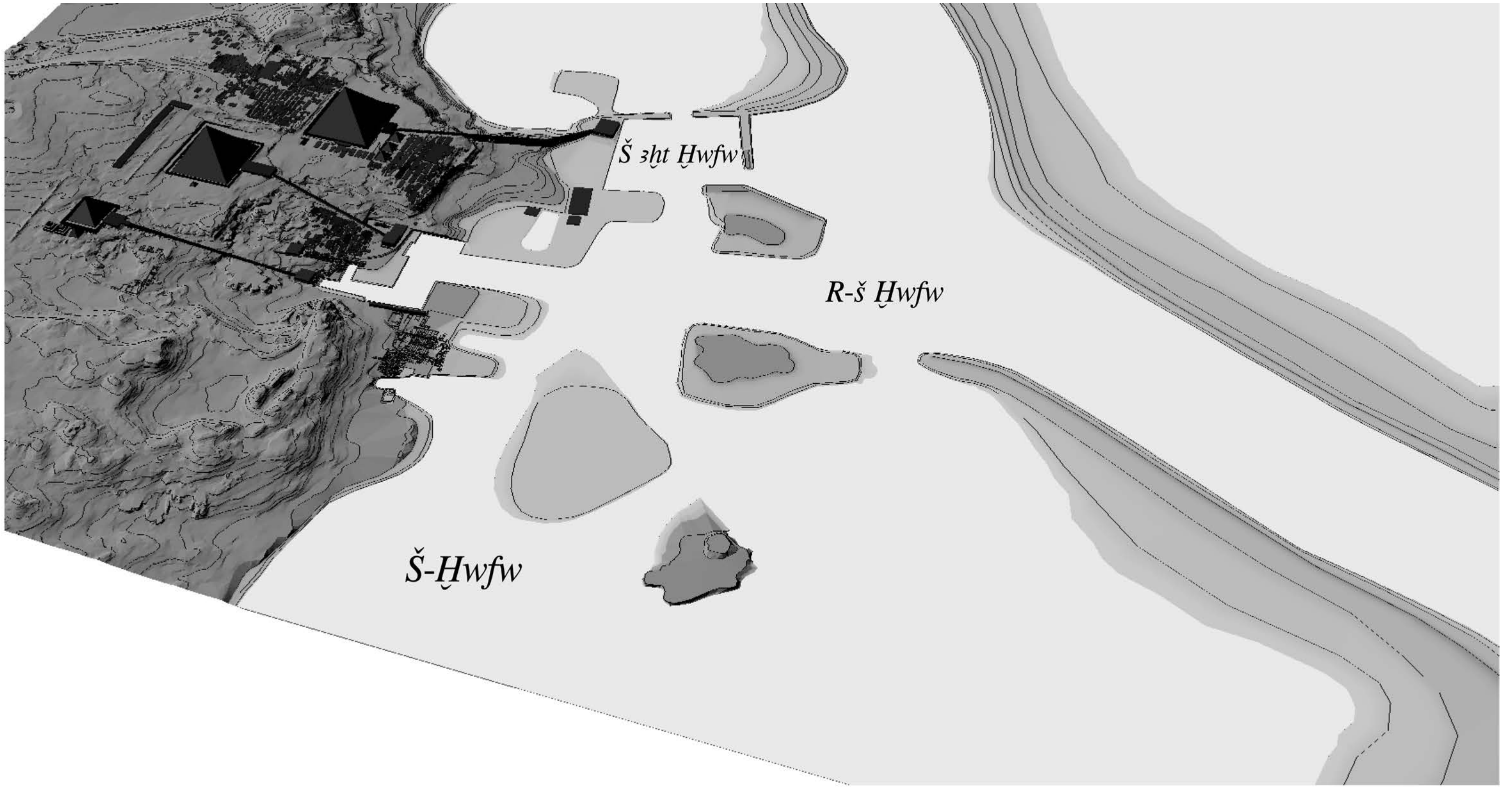

Figure 11.32 Reconstructed Dynasty IV floodplain and water transport infrastructure at flood peak with a water level at 13.5 m asl. View from the southeast to the northwest. Graphic by Rebekah Miracle from AERA GIS.

between the Heit el-Ghurab and Nazlet el-Batran East, would be nearly submerged, or nearly flush with the water, at 14 m asl (based on B221, B239 and B266).

This water level would leave on this landscape one continuous expanse of water from Lagoon 1 to the central canal basin (Fig. 11.32). Perhaps this whole expanse of water was known as She Khufu in Merer's time. Water would fill the southern catchment (the suggested *Š-Ḫwfw*) about 4 m deep, which is enough for Merer's cargo boat. The water would spread farther east than the southern catchment (Fig. 11.31), but there it would be only 1.5–2.0 m deep over the floodplain at 12 m asl.

According to the model, at two broad places, water would overflow from this broad expanse directly into the central canal basin, but only the Nazlet el-Batran side channel would be deep enough for cargo transport. To get into the central canal basin Merer's crew would have taken the channel that curved around past the Nazlet el-Batran mound. This channel would also be about 4 m deep during a flood peaking at 14 m asl. Draughts of the largest cargo boats in the early nineteenth century CE, the 160-ton *falukka* and the 200-ton *markab*, ranged around 2.3–2.5 m, as Cooper (2014:111–12, table 7.2) explicated from the published records of Le Père (1809:123). Tallet (2017:119–27) estimates a single boat, 25–30 m long, for Merer's team of 40 men and their load, perhaps as much as 70–80 tons, or about 30 blocks at 2.5 tons each.[75] A flood only half a meter lower (13.50 m asl) would leave exposed that higher ground between the Heit el-Ghurab and Nazlet el-Batran East (Fig. 11.32), but fill the Nazlet el-Batran channel to a depth of 3.5 m, getting close to the draught of the heaviest cargo boats, but that channel would still be passable at peak flood, through a narrow window in time before the flood began to recede.

As such, the catchment as I reconstructed it south-southeast of Heit el-Ghurab could have been the *Š-Ḫwfw* along the lines that Tallet (2017: fig. 22) construes as a fit to the topography indicated in Merer's journal. By taking the side channel corresponding to the curving waterway through Nazlet el-Batran (separating east and west parts of the settlement), Merer and his men could have sailed from the *Š-Ḫwfw* into the central canal basin without passing through the *R-š Ḫwfw* – the gateway between Nazlet el-Sissi and Nazlet el-Batran East, but only near peak flood.

We could contour the southern catchment deeper – down to the base of the clay and silt on sand as detected in B221, B225 and B226 at 7 m asl, and so too the mouth of the Nazlet el Batran connector canal. This would give a depth of 6.5–7 m with a flood peaking at 13.50–14.00 m asl, more than enough for a cargo boat to pass. However, it is hard to reconstruct the connector canal at this depth because we find clay bottoming out around 10.60 m asl in B239 and B222. Whether the bed of the southern catchment – the possible She Khufu – lay at 7 or 10 m asl, or somewhere in between (the range of the deep silt and clay), it would have been dry, or nearly during low Nile season.

According to the model, the basin east of the Khufu Valley Temple (*Š ꜣḫt Ḫwfw*) and the central canal basin would retain water all year round, albeit to a depth of 1-3 m during low water. If the Egyptians of Merer's time needed a perennial body of water to qualify as the She Khufu, as distinct from the Ro-She Khufu and the She Akhet Khufu, it could only have been, in this model, the central canal basin, a body of water that would spread into the southern catchment during inundation. However, through most of Egyptian history, named basins were both tracts and land and bodies of water. It would have been normal if She Khufu were dry for part of the year.

Even if She Khufu referred strictly to the central canal basin, on this model Merer's cargo boat could have entered it from the south, via the (smaller?) westerly river branch, through the broad catchment south and east of Heit el-Ghurab, and by way of the Nazlet el-Batran side channel, without going through the Nazlet el-Sissi–Nazlet el-Batran gateway, which was possibly the Ro-She Khufu.

So far, this is the best I can translate the topographical, geological and archaeological evidence into a model of Dynasty IV water transport infrastructure and the best I can match that model to Merer's journal, an amazing textual window onto Khufu's transformations of the Giza landscape and riverscape.

Conclusion: Truth in/and Modelling

Is this model of the Giza pyramid builders' water transport infrastructure true? Is this how Dynasty IV structured the floodplain?

The model presented above was the result of a heuristic exercise – that is, it is based on inferences based on rules, with a view to forming an adequate impression from the data. In modelling Dynasty IV water transport infrastructure at Giza, we learn about modern surface contours as vestiges of ancient features, ancient features as encountered through excavation, and the interpretation of sediments as retrieved by deep drilling and logged. The model is a way to engage the data, and to understand drill cores with respect to the built environment (like the Zaghloul Street Wall).

As Hermon (2012:21) states:

> Three-dimensional visualization is an efficient method of visualizing a large amount of data originating from different sources, thus enabling problem-solving. [...] [V]isualization is an ideal means for validating hypotheses, running tests, performing predictions and simulating behaviour under different circumstances and processes in a given period.

Here the predictions relate to how archaeological structures exposed through excavation cohere with drill core data, surface contours and, very recently, textual references (Merer's journal) to the Dynasty IV floodplain below the Giza Plateau. We can test reconstructed elevation values for major landscape features – high and low water levels, levees, floodplain and people's interventions – against the behaviour of the Nile inundation wave.

We can be certain that some kind of great enclosure, defined at least in part by stonewalls or dykes, stretched 500 m east of the Khufu Valley Temple. Benchmarks given by these and other structures, such as the pavement of the Khufu Valley Temple, tell us that the contour values of the model (between 10 and 16 m asl) must be close to true. Evidence points assuredly to a long, broad and very deep channel leading straight toward the Sphinx and Khafre Valley Temple, with two settlements flanking its access on the east. Certainly, Heit el-Ghurab, the so-called 'Lost City of the Pyramids' or 'Workers' Town', flanked this broad delivery zone on the south; and at its southern end Standing Wall Island (perhaps a corral and abattoir) and Lagoon 1 are fact. In the last few years we have found the northern end of a terraced, artificial basin east of the Khentkawes complex, 300 m west of Heit el-Ghurab and 2.2 km west of a Nile channel, if a Nile channel followed the course of the Libeini Canal. If we imagine Nile water filling these basins, it must have come in from the south and east.

In some broad strokes, then, the model must match the Dynasty IV engineered flood plain. It is satisfying to integrate, in some broad patterns, textual evidence from Merer's Journal (Tallet 2017:83–93, 149–61). The biggest unknown remains the course and scale of proximal river channel(s). In subsequent harbour heuristics, we can try other models, keeping to the hard data as givens.[76]

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Notes

1 'Dans le cas de la Djenet de Ro-Shé Khoufou, au vu de l'usage régulier des lieux comme point de mouillage, on pourrait penser à une digue aménagée en pierre, permettant de constituer un abri sûr pour une flotte' (Tallet 2016:11).

2 Pierre Tallet kindly shared with me a pre-publication draft of his 2015 article, which augments extracts from Merer's journal sampled in an earlier work (Tallet 2013). He also most generously sent me the text of his publication of the journal (Tallet 2017). This impressive work was an inundation of new information that I had yet to absorb fully when writing this chapter. Several terms in Merer's journal relate to structures and places in the land- and riverscape that Merer and his team experienced on their many round trips from Tura to Giza.

3 Measured off the 1977 MHR map sheet H-26.

4 Butzer *et al.* (2013) dubbed it the 'Menkaure Wadi'.

5 Compare Dahshur, where dumps of limestone debris from ancient construction surround the Bent Pyramid with a 100 m radius, and that pyramid's valley temple with a radius of 300 m (Bebermeier *et al.* 2011:334).

6 In 2004 AERA and Giza Inspectorate team members documented pottery, wooden objects, rope, string, cloth, lithics and animal bone from the Rowad Trench in the storeroom and field lab that the Giza Inspectorate has provided the AERA team through the years. The material was later moved to the main Ministry of Antiquities storeroom at Giza, west of the northern entrance to the plateau.

7 Investigators came to a similar conclusion about the Dynasty IV pyramid builders using the wadis at Dahshur (Bebermeier *et al.* 2011:348).

8 Bebermeier *et al.* (2011:346) see in the cores outside the mouth of this wadi (catchment IV) as evidence for 'fan deposits […] in a cultural layer (unit 5) indicating wadi activity in the last 5,000 years and consequently single heavy rainfall events sufficient to generate runoff in the main channel.'

9 The burials, in a grotto into the northeastern face of the *gebel*, were robbed during the 2011 revolution.

10 The authors wrote: 'Some 10 flood surges ravaged the Lost City between the end of the Khafre's reign to the beginning of Userkaf's, a span of ~40–45 yr […] and a recurrence interval of once in 4 yr. […] Yet after the formal Gallery had been demolished, on or adjacent to the channel, the same sectors were rebuilt or remodelled for other kinds of use five or more times' (Butzer *et al.* 2013:3362, 3363). Butzer repeats and builds upon this narrative for broader inferences about climate and environment: 'At Dynasty 4th Giza, desert sediments document at least 11 distinct flood events during the reigns of Khafre, Menkaure, and probably Shepseskaf.' For reasons stated here (and more), I must say, with great respect for Professor Butzer's enormous contributions, that this narrative of repeated 'catastrophic wadi flood surge[s] and excessive rains [that] destroyed the quasi-liquefied Galleries with a violent debris flow' (Butzer 2016: fig 6) is largely fictive.

11 The 'gross stratigraphy' of fig. 13 in Butzer *et al.* (2013) is based on Butzer's (2001a) sketch profile of BBHT-2, one of the backhoe trenches in the northeast part of the site. In fact, this section shows open-air bakeries and rebuilds of bakeries, such as we have recorded throughout this area east of the galleries. We have excavated these bakeries by phase. In particular, in 2006–2007 we excavated at the western end of the backhoe trench we had designated BBHT-2 (Lehner *et al.* 2009b:30–4, 44–59). As elsewhere in the site, we found two distinct, coherent, main phases. In the early phase inhabitants baked with large bread pots common to the Old Kingdom and produced faience. In the later phase, they intensified baking in open-air bakeries defined by fieldstone walls. The multiple rebuilds are characteristic of zones of intensified industrial baking. People, not wadi floods, demolished and rebuild the bakeries. We have recorded multiple rebuilds of such baking facilities elsewhere in the area. Butzer *et al.* (2013:3355) see here 'four horizons of sherd rubble ("sherd soup") created by four floods that destroyed pottery kilns', and then 'water-reworked eolian sands, blown up from a temporarily inactive wadi bed', and then a '5th cycle of rebuilding'. They make no reference to the published results of our 2006–2007 excavations.

12 Concerning the use of the Dahshur wadis for 'transportation of allochthonous building material from the floodplain of the river Nile', Bebermeier *et al.* (2011:348) asked 'whether these activities accelerated natural processes such as soil erosion, sediment production and runoff during the construction period of the Bent Pyramid'.

13 In recent years a huge embankment of red gravel and cobbles was laid down over the tail end of the wadi for a new road from the pyramids to the Panorama.

14 Nile valley dwellers would construct spurs from the banks to 'train the river' by collecting sediments and turning its course (Willcocks and Craig 1913, I:288, II:532–3). We have seen traces in the sand of a couple of other possible fieldstone spurs coming into the wadi at sharp angles with its flanks, both upstream and downstream of this juncture. It requires further clearing to confirm these features.

15 We do not see a channel length of ~5.5 km as reported by Butzer *et al.* (2013:3341).

16 In their fig. 12, Butzer *et al.* (2013:3355), represent schematically the sections of our 2001–2002 WCE (Wall of the Crow East) excavation trench. They characterise their layer 7, below the granite debris (their layers 5–6), as 'sludge of organic sandy loam' and 'debris flow with blocks of gallery mudmass moved by violent floods'. In this horizon (their layer 7), directly below the massive dump of granite waste and immediately under the cut, we found intact gallery floors and structures, where these features had not been heavily pitted by Late Period burial pits. Butzer *et al.* (2013) misrepresent this fact. They also do not represent the Late Period burial cuts through the dump of granite waste in their fig. 12. Jessica Kaiser and AERA team members excavated more than 14 Late Period burials that had been placed in pits cut through the granite deposit (Layers 5–6 of Butzer *et al.* 2013: fig. 12). The cuts of burial pits that we excavated, and others we did not excavate, took up most of the trench at a rate of one burial cut per linear metre. Butzer and co-authors only mention 'upcasts of Saite Burials' cut down into 4 and 5 in their layer 3a.

17 Butzer *et al.* (2013) and Butzer (2016) make no reference to this 2006 work.

18 However, neither Reisner nor we see evidence that 'the MVT [Menkaure Valley Temple] apparently suffered flood damage on four or five occasions, two or three during Shepseskaf's reconstruction and two during the later 6th Dynasty' (Butzer *et al.* 2013:3358).

19 As visualised in Lehner (1985a:127, fig. 3C).

20 Willcocks and Craig (1913, II:233: table 131) give mean widths of the Nile at successive water levels. In the stretch from Koshesha near the Fayum entrance to Cairo, the Nile width ranges from 450 m at low water (elevation 12 m asl) to 1700 m at high water, which is 9 m higher (elevation 21.00 m asl).

21 Willcocks (1889:38) stated that the Nile inundation overflowed its banks about eight or nine times a century.

22 'Plenitude was not the maximum level reached by the river in a given year, but rather the point at which the river was deemed to have achieved the level required for normal irrigation of most agricultural lands, and thus the payment of the *kharaj* [land tax]' (Cooper 2014:108). Willcocks (1889:38) stated people began to fill the basins around mid-August.

23 The feeder canals swung off openings in the levees to deliver water into the low basin lands, where these canals tailed off. As for the depth of the feeder canals at their openings into the Nile channel: 'The beds of these canals are almost midway between low Nile and ground level, i.e. about 3 or 4 metres below the level of the country, or the same depth below ordinary flood. The canals are consequently dry during winter and summer' (Willcocks 1889:37).

24 'In more northerly locations in the Nile Valley, the frequency of winds with a northerly component increases significantly during summer, reaching its peak at the height of the Nile flood' (Cooper 2014:128).

25 On the western Nile channel: for Upper Egypt see Butzer (1976:35); for the Memphis-Saqqara area see Giddy (1994), Jeffreys and Tavares (1994) and other publications of the Egypt Exploration Society's Memphis Survey; for the stretch from Giza to Abu Roash see Jones (1995), El-Sanussi and Jones (1997), Butzer (2001a), Lutley and Bunbury (2008), Jeffreys (2008) and Bunbury *et al.* (2009). Lehner (2009:102–10) summarises these sources. On the idea that the western Bahr el-Libeini is a relic of a former Nile channel, for references see Jeffreys and Tavares (1994:155, n. 77).

26 See Jeffreys and Malek (1988:23), Giddy (1994:193–4), Jeffreys and Tavares (1994:157) and Jeffreys (1997:3; 2006:135). The distance from the Shubramant Canal, close on the Saqqara escarpment, to the Libeini Canal along the western side of the Memphis ruin mound is 1.6 km. Jeffreys and Tavares (1994:159) recognise the possibility of the two settled banks when they state that Old Kingdom settlement moved to a high-lying eastern bank under the western side of the Mit Rahina mounds, specifically Kom el-Fakhry.

27 In fact, much of the Nile flows against the eastern side through Upper Egypt (Barois 1889:13).

28 Several authors (Popper 1951:241–7; Butzer 1959:56–8; Said 1993:59; Jeffreys and Tavares 1994:157–8; Seidlmayer 2001; Graham 2004) have shown that the aggradations of silt on the floodplain could not have been at a regular rate. Rather, it varied at different times. At Giza we estimate a total rise of about 4.5 m over 4500 years since Dynasty IV (from roughly 12.50 m asl to 17.00 m asl) – not, however, on the basis of an assumed regular rate (Lehner 2009, esp. 98–9).

29 Measured off Google Earth with its ruler function, 50 m south of the barrages comes to above Dahshur, so Willcocks might have meant 50 km of river length. The profile across the Saqqara and Helwan basins, on the west and east (nos. 73 and 134 in the British numbering) give us the profile of the floodplain at the latitude of Saqqara. Earl (2011:71–2) produced a profile of the valley floor at the latitude of Abusir from the 1937 1:25,000 map of Egypt, which also shows the rise on the east and a drop of 2.5 m over 4 km. The profile shows a slight convexity to the Libeini Canal, running in the trough.

30 For a review of the evidence that Hawass (1997: figs. 1–2) presented see Lehner (2009:110, pls. 8–10, 15).

31 Hassan (2010:137) gives 50–70 m for the width of other secondary Nile channels. Willcocks (1889:77–8) gives 70 m as the bed width of the Sohagiya Canal at its head, 50 m as the bed-width of the Bahr Yusuf and 7 m as the maximum depth of its water (see also Garbrecht and Jaritz 1990:149–50).

32 Toussoun (1925:174) thought just the opposite, insofar as his 'la branche de Manha' corresponds, in part, to the Bahr Yusuf: 'Il est plu que probable qu'elle a été creusée au commencement par la main de l'homme, mais avec le temps et le fonctionnement, elle a pris l'ampleur et le caractère d'une branche naturelle.'

33 Already in the *Atlas géographique,* surveyed in 1799, this dyke appears, labelled *Grande Digue l'Ouke-cheichy*, ending on the east just below El-Oûstah, the modern town of el-Wasta by which the area is known primarily today just a little farther north of the modern barrages. The mighty (168 sq km) Koshesha basin (no. 67 in the British numbering), used to 'hang over Lower Egypt like a dark cloud over the latter half of October' because it received so much water from basins through Middle Egypt (Willcocks 1889:78–9) via the Bahr Yusuf as the common 'escape channel' into the Koshesha basin as well as into the Fayum. Rushdi Said (1993:188–9) states that the Koshesha dam 'forms today a flood barrier for the whole of the Giza province', and has a maximum height of about 15 m and a crest length of some 450 m, although he does not specify whether this is the older dike or after modern modifications.

34 Alleaume's (1992:317, fig. 2) map showing her extraction from the Napoleonic maps of dykes and canals from Armant to Qena shows no such lateral watercourses. Hence her secondary network starts at Qena.

35 'Bien que leurs prises soient généralement établies au-dessus du niveau des basses-eux dans le fleuve, tous retrouvent de l'eau à quelques kilomètres en aval du point où ils le quittent, dès que leur lit rejoint la ligne de bas-fonds qui borde la montagne' (Alleaume 1992:306).

36 This is a point I have yet to verify. Drains and escapes (*collecteurs*) took excess fresh water or already-used water off an area, rather than delivering fresh water for irrigation. See Willcocks and Craig (1913, I:425): 'All irrigation canals need escapes to carry off their excess supplies, and drains to carry off excess waters of the irrigated fields. The drainage water is subdivided into surface water, and infiltration water which has soaked through the soil. In really scientific irrigation and drainage all these three waters are treated separately. In Egypt the escape water and drainage water have to be carried in one and the same channel.'

37 Nowadays, the valley at the latitude of Memphis is 7 km wide, from the mouth of the Wadi Tafla to the edge of the eastern low desert. Valley width increases to 7.5 km at Abusir, 8.92 km (southwest to northeast) from Giza to Old Cairo, and 15.37 km from Abu Roash to Moqattam near the Citadel.

38 The terrace on which the Roman fortress was built 'represents the position of a paleo-channel formed as the Nile entered a period of bed erosion in the Late Paleolithic' (Sheehan 2010:25). The terrace here extends at elevation 10–12 m asl, at or slightly lower than our best estimate for the Dynasty IV floodplain east of Giza. Sheehan (2010:26) notes a 'natural tendency of the channel to follow the eastern edge of the valley' through historical times.

39 In reconstructions from ancient textual, archaeological and geological sources, multiple ancient channels depart from a primary stem, or a major split of two main channels, generally north of where Cairo is today (Butzer 1976:24, fig. 4; Said 1981:82–3, fig. 52).

40 According to Bridge (2003:305), 'it is common in deltas for one or more of the distributary channels to be carrying the bulk of the sediment load'.

41 Stanley and Warne (1993) suggest that the Delta distributaries were most numerous around 6000 BP.

42 Bunbury and Jeffreys (2011), as well as Graham (2010), see the erosion of the outward bank in bends as the primary mechanism for the lateral migration of the river channel. This is the 'Classic Point Bar Model', in which 'the migration of a meandering alluvial channel occurs through the erosion of the outer concave bank of a bend and the deposition on the inner convex bank' (Graham 2010:126). There is a tendency to then see the river destroying any settlement site in the direction of its lateral migration: 'Migration of the river destroys all the settlement on the erosional side of the river and

preserves only sites on the depositional side (Lutley and Bunbury 2008:4; also Bunbury and Jeffreys 2011:67; Sheehan 2010:38). This view ignores lateral river migration through avulsion. Literally 'a tearing away', avulsion occurs when a river suddenly breaches its levee and cuts a new channel, and it is 'the process whereby a channel belt shifts relatively abruptly from one location to another on the floodplain surface in favor of a new gradient' (Bridge 2003:308).

Because avulsions happen when floodwater flows into a *crevasse channel* breach, the Egyptian Nile must have been especially susceptible. Many breaches, 3–4 m deep, opened off the Nile levees as the heads of feeder canals that flooded the adjacent basin lands. Bridge (2003:317) states as a necessary condition that 'the water level in a floodbasin must be lower than that in the main channel to allow water to flow away from the main channel through a crevasse channel. When the water surface elevations of the main channel and the floodbasin are the same, there can be no such crevasse-channel flow. Therefore, the processes of crevasse-channel enlargement […] can only operate during certain overbank flood stages.' He also notes that human intervention can increase or decrease river avulsions (Bridge 2003:311): 'It has been suggested that channel belts are capable of gradual migration across their floodplains by preferential net bank erosion along one side of the channel belt and net deposition on the other side […] However, evidence for such movement is rare or equivocal in modern rivers. […] [A]vulsions appear to be the most important means of moving channel belts around most natural floodplains' (Bridge 2003:326).

Through avulsion rivers can migrate without erasing everything in the direction of their floodplain crossing. If the avulsion occurs upstream of a higher land mass, a natural 'turtleback' and/or a settlement mound, the new channel may well go around the mound on the opposite side of the old channel, a process of *island formation and capture* that retains older high ground, which might host settlement. This is a very different process than bar and island formation nearly flush with low or median water level in the deep Nile channel. Any such island or bar near low-water level would have been covered by water up to 7 m deep during the peak of the inundation. Avulsion could well have been a mechanism that created the 'Islands of Memphis'. As channels avulsed from west to east of Mit Rahina, old ground was preserved.

Menes's diversion of the Nile in founding Memphis is a legendary Nile avulsion. For another legendary avulsion of the same order of magnitude on the Yellow River, also controlled by a founding ruler, Yu, of the Xia dynasty, now substantiated archaeologically, see Wu *et al.* (2016) and Montgomery (2016).

43 The construction of barrages, weirs and other 'river training' structures, which began to be built in 1833 and culminated in the barrages completed in 1861 across the Rosetta and Damietta, radically changed the head of the Delta as mapped by the Napoleonic Expedition (Willcocks 1889:148–9, 177–8, pl. XVIII). The first of the large islands upstream of the bifurcation, labelled Geziret el-Chalaqan on the French map, became the southern tip of the Delta head when the cross-canal on the north of it silted up as water was diverted into three irrigation canals, from west to east: Rayah Behira, Rayah Menufiya and Rayah Tefiki (Willcocks and Craig 1913, II:125, fig. 152). Today, Geziret el-Waraq maintains the same basic shape as in the *Atlas géographuque*, pl. 24.

44 Measuring off the 1977 MHR 1:5000 map sheets from an estimation of the northern end of el-Azizeyah (Ezbet Nagati) to the southern end of Tell el-Qala'ah.

45 While Tura to Giza is 15 km as the crow flies, Tallet (2016:11–12) suggested that 'il est très vraisemblable que la navigation, tributaire d'une hydrographie complexe, ne s'effectuait pas en droite ligne d'un point à un autre, ce qui augmente sans doute légèrement les distances parcourues.'

46 See note 25. Also see Jeffreys (2010:5–87, 73) for the opinions of several authors and travellers, going back through the centuries to Herodotus, that the Bahr Yusuf and Libeini mark the ancient bed of the Nile.

47 As El-Sanussi and Jones (1997:249) state: '[T]he Bahr el-Libaini flows […] in its own small valley which has never risen to the same level as the adjacent fields'.

48 The modelling is *heuristic* insofar as the visualisation draws together disparate information – features, benchmarks and spot heights on the Dynasty IV topography – and generates insight, understanding and new questions. It is my intention to fully reference the sources from which I compose a model

or a visualisation, in effect to 'footnote' a reconstructed landscape (see Lehner 1985a). Toward that end, I find myself in agreement with basic principles of the London Charter (2009) on the transparency of materials and evidence (I thank Donald Sanders [2012] for introducing me to the London Charter). See Bentkowska-Kafel *et al.* (2012), and in particular Hermon (2012) in that volume. I have tried to model the bathymetry of the waterways as basins; that is, to contour them from top to bottom with values that reflect our best estimates for the Dynasty IV landscape, so as to test how the pyramid builders might have utilised the tremendous hydraulic lift of the annual Nile inundation wave. Knowing the extent to which we match ancient realities always requires further information to test the series of inferences and hypotheses from which we form the model.

49 See note 50.

50 Note that most of the published reconstructions and inferences about ancient landscape, settlement and river movement based on core drillings in the Memphite zone have, so far, offered very little or nothing of the core logs themselves – that is, the primary data. For profiles of the floodplain below the Giza Plateau based on logs of the AMBRIC borings, see El-Sanussi and Jones (1997: fig. 3) and Butzer *et al.* (2013:3345: figs. 3–4). See Butzer *et al.* (2013: fig. 2A) for a location plot of the most of AMBRIC borings east of the Giza Plateau.

51 Butzer *et al.* (2013:3344–7: fig. 3b, d–e, fig. 4), citing Hawass (1997) and Lehner (2009).

52 See and compare El-Sanussi and Jones (1997:244, fig. 3) and Butzer *et al.* (2013: figs. 3–4).

53 Butzer (2016:72) seems to have this higher contact in mind when wrote that 'after a pause with a few meters erosion, Nilotic aggradation resumed', but he gives an elevation range of 9–10 m asl. If I understand correctly, Butzer (2016:72) would probably see the early Holocene branch, cut into the Pleistocene sand, as out of phase by the time of any mid-Holocene channel that might have serviced the Dynasty IV pyramid builders (Butzer 2016:74). However, I will leave this point in question.

54 *Ḫmw n [ꜣḫt]-Ḫwfw* is determined with the *niwt* sign, as opposed to the prior mention of Akhet Khufu, but see Tallet (2017:64, n. c).

55 Hawass (2005:320–1) gives 14.00–14.20 m asl. It is my recollection that Michael Jones, who supervised the work for Hawass and AMBRIC reported in personal communications 14.50 m asl as the elevation of the basalt pavement, and so I reported thus (Lehner 2009:105, 142).

56 See note 28.

57 Michael Jones monitored this trench and drew a section of the two-phase settlement remains that the trench cut south of the Abu Taleb bridge, which Hawass (1996:57, fig. 1) published.

58 People dump trash into canals and basins. In premodern times much of the trash consisted of pottery, so we could expect pottery and settlement material in channels and basins at very low elevations (Jones 1995:91, 96). Also, 'sherds […] could be carried by the strong currents of the Nile in flood, whose scouring effect might well create a bed as deep as 40 feet (12 metres)' (Jeffreys 2010:95). In the area of my reconstruction, pottery was detected at elevation 7.39 m asl in borehole B215 (Fig. 11.15), which comes in the middle of my reconstructed Nile channel (see El-Sanussi and Jones 1997:250, where B215 = Boring 8). It is the consistency and coherence of pottery logged within a certain elevation range – 12–14 m asl, and 14.5–15 m asl (El-Sanussi and Jones 1997:250) – that determines settlement bounding waterways. In my modelling I am impressed by the number of cores that log pottery in the range of 14.80 (average 14.74) m asl along the base of the escarpment east and north of the Eastern Field. I infer from this settlement on the higher land of a western levee (Lehner 2009:110–12, 142).

59 Such shallow depth of low water fits with what we know of the Nile in recent centuries (Cooper 2014).

60 The ancient dyke at Illahun separating the Koshesha basin from the Fayum depression rises nearly 8 m with a slope of 1/3 on the Fayum side (Willcocks and Craig 1913, II:442, fig. 31; for the 2/1 slope of basin banks, see 608, fig. 141).

61 Recounted by Kamal Waheid and Michael Jones, who monitored the AMBRIC trenching for Zahi Hawass and the Giza Pyramids Inspectorate.

62 In a photograph that Reisner (1942: pl. 5a–b) published, you can see both village mounds rising above the floodplain during dry season, and the Amirah Fadya Street track from Nazlet el-Sissi to the edge of the low desert sand.

63 Along the base of the plateau, closer to the Khafre Valley Temple and Sphinx Temple, sand accumulated much higher (up to 20–1 m asl) and forms the modern surface.

64 Hawass (1997:246–7) reported on this borehole based on notes, a log and photographs of the core samples that I took in 1980. I was working at the Sphinx with the ARCE Sphinx Project as a team carried out the core drilling and brought up the samples ('Core Drilling East of the Sphinx Temple, September 1980, Notes by Mark Lehner: Core Drilling Designated "P1"' – report on file, Ancient Egypt Research Associates).

65 Tallet points out this may be the same place named *ʿn(ḫ) Ḫwfw*' in a series of estates shown in the tomb of Meresankh III (Dunham and Simpson 1974:10, pl. IV, fig. 4). The same name, with a slightly different orthography, occurs in the tomb of Mer-ib Kaipunisu where *R- š Ḫwfw* is also listed (Baud 1998:35–40, 458).

66 The tables that Willcocks and Craig (1913, II:610, table 227) give for the depth of water in flood, summer and winter in the main canals of Menufia and Gharbia (Delta) might suggest their beds were higher than the Nile branches, although they quote C.E. Dupuis (Willcocks and Craig 1913, II:612) that the usual practice in digging small branch canals 'is to dig them so deep that, even with the lowest summer levels in the main line, they draw their fair share of water'. Their table 230 (Willcocks and Craig 1913, II:625) shows that canal depth is a function of width.

67 Tallet cites Zibelius (1978:135) for the, heretofore, oldest attestation in the reign of Menkaure.

68 Tallet considers that 'Tura North' could have referred to Moqattam, but he excludes identifying Tura North with Moqattam because Merer's journal uses the term 'to fare downstream' (*m-ḫd*) when coming from Tura North to Giza. Northernmost Tura is still south-southeast of Giza, and the team had to navigate from south to north, with the current, to get from Tura to Giza.

69 Given that Merer's journal dates to Year 26 of Khufu, toward the end of his reign, the causeway corridor, with its decorated internal cladding of fine limestone, should have been nearing completion. In fact, some of the fine limestone that Merer delivered might have been for the causeway, the upper pyramid temple, the pyramid court and enclosure wall, and the valley temple.

70 On the northeast part of the Heit el-Ghurab, we lose the Dynasty IV settlement to a broad horizontal exposure of a concentrated, thick sequence of alluvial silt and sand layers on a gradual dip down to northeast. Nile floods left laminated silt layers and stained the underlying sand grey almost as far west as to the end of the Wall of the Crow (Lehner *et al.* 2009b:115–24). We now know that scouring and erosion removed the northeast corner of the site at some point after the Old Kingdom occupation.

71 Later, Butzer *et al.* (2013:3350) add: 'But digging out a basin would have required removal of at least 5 m of sandy wash […], yet massive spoil-heaps such as at Malqata […] are absent. Were they totally removed, and perhaps used to dam up part of the wadi flow to prevent sediment from silting up a possible harbor?'

72 The situation of this Dynasty IV royal settlement arrayed south of the basin and delivery area at Giza, might bear some comparison with the 'palace city' of Malqata, laid out at the northern corner of the Birket Habu.

73 See Lutley and Bunbury (2008:5), where their map shows the Nile of 2500 BCE just west of the Libeini).

74 While the photograph came with a handwritten date of 1928 on the back, we can see (right centre) the Khentkawes Town already excavated by Selim Hassan in 1932.

75 Of course, the Tura limestone casing blocks were not of uniform size and weight. Some of the largest casing blocks at the bottom of the Khufu Pyramid might weigh as much as 15–17 tons, while near the top, casing blocks would be smaller slabs, like those still preserved near the top of the Khafre Pyramid. See, also for cargo boat loads up to 185 tons with draughts of only 2.20 m, Willcocks and Craig (1913, II:594, table 225).

76 I wrote this article in 2016, before the first of two workshops held in Cairo on Egyptian Riverine Harbours in September 2017 and 2018, organised by Irene Forstner-Müller (ÖAI - Cairo), Harco Willems (KY Leuven) and Marine Yoyotte (Ifao - Cairo). The article now appears after the third such meeting, broadened to The First Symposium of the Workgroup Egyptian Riverine Harbours. I presented the model proposed here to these meetings, and received critical feedback. The article appears here, with editing, as I wrote it in 2016. I hope to convey and comment on the critical review in future modeling based on the evidence presented here and any further information from ground truth at Giza.

References

Abbreviations

PM = Porter, B. and R.L.B. Moss (1960 onwards) *Topographical Bibliography of Ancient Egyptian Hieroglyphic Texts, Reliefs and Paintings.* 2nd edn. Oxford: Oxford University Press.

Other Works

AERA Annual Report (2011) The Khentkawes basin and the town beyond. In *Working Through Change: AERA Annual Report 2010–2011*. Boston: Ancient Egypt Research Associates, pp. 6–11.

Aeragram (2001) When the desert was in flood. *Aeragram* 5(1):3–5.

Aeragram (2011) KKT-E+: the buried basin and the town beyond. *Aeragram* 12(1):10–13.

Aeragram (2012) Conundrums and surprises: the Silo Building Complex. *Aeragram* 13(2):6–9.

Aeragram (2014) Construction hub to cult center: re-purposing Old Kingdom style. *Aeragram* 15(1–2):2–5.

Aeragram (2015) The Gallery Complex gives up some of its secrets. *Aeragram* 16(1):12–16.

Aigner, T. (1981) *Fazies und Ereignis-Schichtung im Mittel- und Ober-Eozän von Ägypten*. Diploma thesis, Eberhard-Karls-Universität, Tübingen.

Aigner, T. (1982) Zur Geologie und Geoärchaologie des Pyramidenplateaus von Giza, Ägypten. *Natur und Museum* 112:377–88.

Aigner, T. (1983a) Facies and origin of nummulitic buildups: an example from the Giza Pyramids Plateau (Middle Eocene, Egypt). *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen* 166:347–68.

Aigner, T. (1983b) A Pliocene cliff-line around the Giza Pyramids Plateau, Egypt. *Palaeogeography, Palaeoclimatology, Palaeoecology* 42:313–22. https://doi.org/10.1016/0031-0182(83)90029-9

Alexanian, N. and F. Arnold (2016) The complex of the Bent Pyramid as a landscape design project. In *10. Ägyptologische Tempeltagung: Ägyptische Tempel zwischen Normierung und Individualität: München, 29.–31. August 2014*, edited by M. Ullmann. Königtum, Staat und Gesellschaft früher Hochkultur 3.5. Wiesbaden: Harrassowitz, pp. 1–16. https://doi.org/10.2307/j.ctvc5pfjr.5

Alexanian, N., W. Bebermeier and D. Blaschta (2012) Untersuchungen am unteren Augweg der Knickpyramide in Dahschur. *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 68:1–30.

Alexanian, N., W. Bebermeir, D. Blaschta, A. Ramisch, B. Schütt and S.J. Seidlmayer (2010) The necropolis of Dahshur: seventh excavation report, Autumn 2009 and Spring 2010. German Archaeological Institute and Free University of Berlin. *Annales du Service des antiquités de l'Égypte*.

Alexanian, N., S. Lösch, A. Nerlich and S.J. Seidlmayer (2008) The necropolis of Dahshur: fifth excavation report, spring 2008. German Archaeological Institute and Free University of Berlin. *Annales du Service des antiquités de l'Égypte*.

Alleaume, G. (1992) Les systèmes hydrauliques de l'Égypte pré-moderne, essai d'histoire de paysage. In *Itinéraires d'Égypte, Mélanges offerts au Père Maurice Martin S.J.*, edited by C. Décobert. Bibliothèque d'Étude 107. Cairo: Institut français d'archéologie orientale, pp. 301–22.

AMBRIC (1989) Greater Cairo Waste Water Project, West Bank Project, Cairo, Contract No. 7: Pyramids Area Sewers and Collectors, vol. 2: Geotechnical Information. Internal report, Arab Republic of Egypt, Ministry of Reconstruction, New Communities, Housing and Utilities Organization for the Execution of the Greater Cairo Wastewater Project.

Arnold, D. (1991) *Building in Egypt: Pharaonic Stone Masonry*. Oxford: Oxford University Press.

Aston, D.A. and D. Jeffreys (2007) *The Survey of Memphis*, vol. 3: *The Third Intermediate Period Levels*. London: Egypt Exploration Society.

Barois, J. (1889) *Irrigation in Egypt*. Trans. A.M Miller. Washington, DC: Government Printing Office.

Baud, M. (1998) *Famille royale et pouvoir sous l'Ancien Empire égyptien*, Bibliothèque d'Étude 126. Cairo: Institut française d'archéologie orientale.

Bebermeier, W., N. Alexanian, D. Blaschta, A. Ramisch, B. Schütt and S.J. Seidlmayer (2011) Analysis of past and present landscapes surrounding the necropolis of Dahshur. *Die Erde* 142:325–52.

Bentkowska-Kafel, A., D. Denard and D. Baker (eds.) (2012) *Paradata and Transparency in Virtual Heritage*. Farnham, UK: Ashgate.

Borchardt, L. (1907) *Ausgrabungen der Deutschen Orient-Gesellschaft in Abusir: 1902–1904*, vol: 1: *Das Grabdenkmal des Königs Ne-User-Re'*. Leipzig: J.C. Hinrichs'sche Buchhandlung.

Branton, T. (2010) Landscape change in the capital zone. Unpublished paper, supervised by J. Bunbury.

Brown, R.H. (1887) The Bahr Yusuf, roughly describing its present state and uses. *Proceedings of the Royal Geographic Society* 9:614–17.

Bunbury, J.M. (2009) Egypt and the global cooling crisis. *Ancient Egypt* 10(1):50–5.

Bunbury, J.M. and D. Jeffreys (2011) Real and literary landscapes in ancient Egypt. *Cambridge Archaeological Journal* 21:65–75. https://doi.org/10.1017/s0959774311000047

Bunbury, J.M., K. Lutley and A. Graham (2009) Giza geomorphological report. In *Giza Plateau Mapping Project Seasons 2006–07 Preliminary Report*, edited by M. Lehner, M. Kamel and A. Tavares. Giza Occasional Papers 3. Boston: Ancient Egypt Research Associates, pp. 97–151.

Bridge, J.S. (2003) *Rivers and Floodplains: Processes and Sedimentary Record*. Oxford: Blackwell.

Butzer, K. (1959) Environment and human ecology in Egypt during Predynastic and Early Dynastic times. *Bulletin de la Société de Géographie d'Égypte* 32:43–87.

Butzer, K. (1976) *Early Hydraulic Civilization in Egypt: A Study in Cultural Ecology*. Chicago: University of Chicago Press.

Butzer, K. (2001a) Under the floodplain at Giza. Unpublished manuscript.

Butzer, K. (2001b) When the desert was in flood… environmental history of the Giza Plateau. *Aeragram* 5(1):3–5.

Butzer, K. (2016) Landscapes and environmental history of ancient Egypt: review and prospectus. In *Gedenkschrift für Werner Kaiser*, edited by D. Polz and S. Seidlmayer. Special issue of *Mitteilungen des Deutschen archäologischen Instituts, Abteilung Kairo* 70/71:59–80.

Butzer, K., E. Butzer and S. Love (2013) Urban geoarchaeology and environmental history at the Lost City of the Pyramids, Giza: synthesis and review. *Journal of Archaeological Science* 40:3340–66. https://doi.org/10.1016/j.jas.2013.02.018

Casey, I. (1999) Settlements at South Saqqara. *Egyptian Archaeology* 15:24–5.

Cooper, J.P. (2014) *The Medieval Nile*. Cairo: American University in Cairo Press.
Dash, G. (2004) Seeing beneath the surface. *Aeragram* 7(1):1, 5–10.
Dash, G. (2012) North by northwest: the strange case of Giza's misalignments. *Aeragram* 13(1):10–15.
Dhennin, S. and C. Somaglino (2016) *Décrire, imaginer, construire l'espace: Toponymie égyptienne de l'Antiquité au Moyen Âge,* Cairo: Institut française d'archéologie orientale.
Dufton, D. and T. Branton (2010) Climate change in early Egypt. *Egyptian Archaeology* 36:36–7.
Dunham, D. and W.K. Simpson (1974) *The Mastaba of Queen Mersyankh III: G 7530–7540.* Giza Mastabas 1. Boston: Museum of Fine Arts.
Earl, E. (2011) The ancient lakes of Abusir. Unpublished research project, supervised by J. Bunbury.
Edel, E. (1956) Beiträge zum ägyptischen Lexikon III. *Zeitschrift für ägyptische Sprache und Altertumskunde* 81:68–73.
Edwards, I.E.S. (1993) [1947] *The Pyramids of Egypt* (revised edition). Harmondsworth, UK: Penguin.
El-Sanussi, A. and M. Jones (1997) A site of Maadi Culture near the pyramids. *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 53:241–53.
Fahlbusch, H. 2001 *Historical Dams*. New Delhi: International Commission on Irrigation and Drainage.
Gale, R., P. Gasson, N. Hepper and G. Killen (2000) Wood. In P.T. Nicholson and I. Shaw, *Ancient Egyptian Materials and Industries*. Cambridge: Cambridge University Press, pp. 334–71.
Garbrecht, G. (2005) Bauwerke für Jahrtausende: Talsperrenbau im Altertum von 3000 v. Chr. Bis 500 n. Chr. *Kultur & Technik* 03/2005:26–31.
Garbrecht, G. and H.-U. Bertram (1983) *Der Sadd-el-Kafara, die älteste Talsperre der Welt (2600 v.Chr.)* Mitteilungen des Leichtweiss-Instituts für Wasserbau der Technischen Universität Braunschweig 81. Braunschweig: Leichtweiss-Institut für Wasserbau der Technischen Universität Braunschweig.
Garbrecht, G. and H. Jaritz (1990) *Untersuchungen antiker Anlagen zur Wasserspeicherung im Fayum.* Agypten Heft 107. Braunschweig: Leichtweiss-Institut für Wasserbau der Technischen Universität Braunschweig.
Giddy, L. (1994) Memphis and Saqqara during the late Old Kingdom: some topographical considerations. In *Hommages à Jean Leclant*. vol. 1: *etudes pharaoniques*, edited by C. Berger, G. Clerc and N.-C. Grimal. Bibliothèque d'Étude 106/1. Cairo: Institut française d'archéologie orientale, pp. 189–200.
Goyon, G. (1971) Les ports des pyramides et le Grand Canal de Memphis. *Revue d'Égyptologie* 23:137–53.
Goyon, G. (1977) *Le secret des bâtisseurs des grandes pyramides Khéops*. Paris: Pygmalion.
Graham, A. (2004) Bed composition degradation and aggradation. Unpublished paper.
Graham, A. (2010) Islands in the Nile: a geoarchaeological approach to settlement location in the Egyptian Nile Valley and the case of Karnak. In *Cities and Urbanism in Ancient Egypt*, edited by M. Bietak, E. Czerny and I. Förstner-Müller. Vienna: Österreichischen Akademie der Wissenschaften, pp. 171–216.
Hannig, R. (2003) *Ägyptisches Wörterbuch*, vol 1: *Altes Reich und Erste Zwischenzeit*. Hannig Lexica 4, Kulturgeschichte der antiken Welt 98. Mainz: Philipp von Zabern.
Hassan, F.A. (1997) The dynamics of a riverine civilization: a geoarchaeological perspective on the Nile Valley, Egypt. *World Archaeology* 29:51–74. https://doi.org/10.1080/00438243.1997.9980363
Hassan, F.A. (2010) Climate change, Nile floods, and riparia. In *Riparia dans l'empire Romain*, edited by E. Hermon. British Archaeological Reports, International Series 2066. Oxford: John and Erica Hedges, pp. 131–50.

Hassan, S. (1938) Excavations at Saqqara 1937–1938. *Annales du Service des antiquités de l'Egypte* 38:503–21.
Hawass, Z. (1996) The workmen's community at Giza. In *House and Palace in Ancient Egypt*, edited by M. Bietak. Vienna: Österreichischen Akademie der Wissenschaften, pp. 53–68.
Hawass, Z. (1997) The discovery of the harbors of Khufu and Khafre at Giza. In *Études sur l'ancien empire et la nécropole de Saqqara dédiées a Jean-Philippe Lauer*, edited by C. Berger and B. Mathieu. Montpellier: Universite Montpellier III, pp. 245–56.
Hawass, Z. (2005) Khufu's national project: the Great Pyramid of Giza in the year 2528 B.C. In *Structure and Significance: Thoughts on Ancient Egyptian Architecture*, edited by P. Jánosi. Vienna: Österreichschen Akademie der Wissenshaften, pp. 305–34.
Hawass, Z. and A. Senussi [El-Sanussi] (2008) *Old Kingdom Pottery from Giza*. Cairo: American University in Cairo Press.
Hermon, S. (2012) Scientific method, *chaine opératoire* and visualization. In *Paradata and Transparency in Virtual Heritage*, edited by A. Bentkowska-Kafel, D. Denard and D. Baker. Farnham, UK: Ashgate, pp. 7–22.
Jacotin, E. (1826) *Description de l'Egypte, ou Recueil des observations et recherches qui ont ete faites en Egypte pendant l'expedition de l'armee francaise*, vol. 37.1: *Atlas géographique*. [*Planches*] (2nd edn). Paris: C.L.F. Panckoucke. https://doi.org/10.5962/bhl.title.14561
Jánosi, P. (2005) *Giza in der 4. Dynastie, die Baugeschichte und Belegung einer Nekropole des alten Reiches*, vol. 1: *Die Mastabas der Kernfriedhöfe und die Felsgräber*. Vienna: Österreichischen Akademie der Wissenschaften.
Jeffreys, D. (1985) *The Survey of Memphis*, part 1: *The Archaeological Report*. London: Egypt Exploration Society.
Jeffreys, D. (1996) House, palace, and islands at Memphis. In *Haus und Palast in alten Ägypten – House and Palace in Ancient Egypt, Internationales Symposium 8 bis 11. April 1992 in Kairo*, edited by M. Bietak. Vienna: Verlag der Österreichischen Akademie der Wissenschaften, pp. 287–95.
Jeffreys, D. (1997) Excavation and survey east of the Saqqara-Abusir escarpment. *Journal of Egyptian Archaeology* 83:2–6.
Jeffreys, D. (2001) High and dry? Survey of the Memphite escarpment. *Egyptian Archaeology* 19:15–17.
Jeffreys, D. (2006) *Survey of Memphis*, vol.5: *Kom Rabia: The New Kingdom Settlement (Levels II–V)*. London: Egypt Exploration Society.
Jeffreys, D. (2008) Archaeological implications of the moving Nile. *Egyptian Archaeology* 32:6–7.
Jeffreys, D. (2010) *The Survey of Memphis*, vol. 7: *The Hekekyan Papers and Other Sources for the Survey of Memphis*. London: Egypt Exploration Society.
Jeffreys, D. and J. Málek (1988) Memphis 1986, 1987. *Journal of Egyptian Archaeology* 74:15–29. https://doi.org/10.1177/030751338807400103
Jeffreys, D. and A. Tavares (1994) The historic landscape of Early Dynastic Memphis. *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 50:143–73.
Jones, D. (2011) The mystery of the Lower Buried Building. In *Giza Plateau Mapping Project Season 2009 Preliminary Report*, edited by M. Lehner. Giza Occasional Papers 5. Boston: Ancient Egypt Research Associates, pp. 17–24.
Jones, M. (1995) A new Old Kingdom settlement near Ausim: report of the archaeological discoveries made in the Barakat Drain Improvements Project. *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 51:85–98.
Jones, M. (1997) Archaeological discoveries in Doqqi and the course of the Nile at Cairo during the Roman period. *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 53:101–11.

Junker, H. (1938) *Giza*, vol. 3: *Die Mastabas der vorgeschrittenen V. Dynastie auf dem Westfriedhof*. Vienna and Leipzig: Hölder-Pichler-Tempsky.

Kemp, B.J. (2006) *Ancient Egypt: Anatomy of a Civilization*. 2nd edn. London: Routledge.

Kemp, B.J. and D. O'Connor (1974) An ancient Nile harbour: University Museum excavations at the Birket Habu'. *International Journal of Nautical Archaeology and Underwater Exploration* 3:101–36. https://doi.org/10.1111/j.1095-9270.1974.tb00863

Klemm, R. and D.M. Klemm (2008) *Stones and Quarries in Ancient Egypt*. London: British Museum Press.

Kromer, K. (1978) *Siedlungsfunde aus dem frühen alten Reich in Giseh, Österreichische Ausgrabungen 1971–1975*. Vienna: Österreichischen Akademie der Wissenshaften.

Kumar, S., K. Shanker and A. Dey (2014) Failure analysis of Sadd el-Kafara: the oldest masonry dam. *Proceedings of Indian Geotechnical Conference (IGC-2014), December 18-20, 2014, Kakinada, India*. New Delhi: Indian Geotechnical Society, pp. 2235–42.

Le Père, J.M. (1809) Mémoire sur la communication de la Mer des Indes à la Méditerranée, par la Mer Rouge et l'Isthme de Souey. In *Description de l'Égypte: Ou, recueil des observations et des recherches qui ont été faites en Égypte pendant l'expédition de armée française*, vol. 5.1: *État Moderne*, edited by E.F. Jomard. Paris: Imprimerie impériale, pp. 21–186. https://doi.org/10.5962/bhl.title.62506

Lehner, M. (1985a) The development of the Giza Necropolis: the Khufu project. *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 41:109–43.

Lehner, M. (1985b) Giza: a contextual approach to the pyramids. *Archiv für Orientforschung* 32:136–58.

Lehner, M. (1997) *The Complete Pyramids*. London: Thames and Hudson.

Lehner, M. (2002) The pyramid-age settlement of the Southern Mount at Giza. *Journal of the American Research Center in Egypt* 39:27–74. https://doi.org/10.2307/40001149

Lehner, M. (2007) Introduction. In *Giza Reports: The Giza Plateau Mapping Project,* vol. 1: *Project History, Survey, Ceramics, and Main Street and Gallery III.4 Operations*, edited by M. Lehner and W. Wetterstrom. Boston: Ancient Egypt Research Associates, pp. 3–47. https://doi.org/10.2307/j.ctvkc67f5

Lehner, M. (2009) Capital zone walk-about 2006: spot heights on the third millennium landscape. In *Giza Plateau Mapping Project Seasons 2006–07 Preliminary Report*, edited by M. Lehner, M. Kamel and A. Tavares. Giza Occasional Papers 3. Boston: Ancient Egypt Research Associates, pp. 97–151.

Lehner, M. (2010) Ascending Giza on a monumental ramp. *Aeragram* 11(1):8–11.

Lehner, M. (2011a) KKT-AI: between Khentkawes Town and the Menkaure Valley Temple. In *Giza Plateau Mapping Project Season 2009 Preliminary Report*, edited by M. Lehner. Giza Occasional Papers 5. Boston: Ancient Egypt Research Associates, pp. 53–92.

Lehner, M. (2011b) KKT-E: notes and reconstructions (foldout 3). In *Giza Plateau Mapping Project Season 2009 Preliminary Report*, edited by M. Lehner. Giza Occasional Papers 5. Boston: Ancient Egypt Research Associates, pp. 29–33.

Lehner, M. (2011c) KKT-E: SLR elevation view (foldout 2). In *Giza Plateau Mapping Project Season 2009 Preliminary Report*, edited by M. Lehner. Giza Occasional Papers 5. Boston: Ancient Egypt Research Associates, pp. 25–8.

Lehner, M. (2011d) KKT-E: valley complex for Khentkawes I. In *Giza Plateau Mapping Project Season 2009 Preliminary Report*, edited by M. Lehner. Giza Occasional Papers 5. Boston: Ancient Egypt Research Associates, pp. 15–16.

Lehner, M. (2013) The lost port city of the pyramids. *Aeragram* 14(1):2–7.

Lehner, M. (2014a) Giza Plateau Mapping Project. In *The Oriental Institute 2013–2014 Annual Report*, edited by G. Stein. Chicago: Oriental Institute, pp. 67–79.

Lehner, M. (2014b) On the waterfront: canals and harbors in the time of Giza pyramid-building. *Aeragram* 15(1–2):14–23.
Lehner, M. (2015a) The Giza Plateau Mapping Project. In *The Oriental Institute 2014–2015 Annual Report*, edited by G. Stein. Chicago: Oriental Institute, pp. 74–96.
Lehner, M. (2015b) Labor and the pyramids: The Heit el-Ghurab 'Workers Town' at Giza. In *Labor in the Ancient World*, vol. 5, edited by P. Stenkeller and M. Hudson. Dresden: Islet, pp. 397–522.
Lehner, M. (2015c) The monument and the formerly so-called valley temple of Khentkawes I: four observations. In *7. Symposium zur Königsideologie / 7th Symposium on Egyptian Royal Ideology: Royal versus Divine Authority: Acquisition, Legitimization and Renewal of Power. Prague, June 26–28, 2013*, edited by F. Coppens, J. Janák and H. Vymazalova. Königtum, Staat und Gesellschaft früher Hochkulturen 4.4. Wiesbaden: Harrassowitz, pp. 215–74. https://doi.org/10.2307/j.ctvc16rtb.14
Lehner, M. (2015d) Shareholders: the Menkaure Valley Temple occupation in context. In *Towards a New History for the Egyptian Old Kingdom: Perspectives on the Pyramid Age*, edited by P. der Manuelian and T. Schneider. Harvard Egyptological Studies 1. Leiden: Brill, pp. 227–314. https://doi.org/10.1163/9789004301894_007
Lehner, M. (2016) The name and nature of the Old Kingdom Heit el-Ghurab site: workers' town, pyramid town, and the port hypothesis. in *The Pyramids: Between Life and Death*, edited by I. Hein, N. Billings and E. Meyer-Dietrich. Boreas 36, Uppsala: Uppsala University, pp. 99–160.
Lehner, M. (2018) Giza Plateau Mapping Project. In *The Oriental Institute 2017–2018 Annual Report*, edited by C. Woods. Chicago: Oriental Institute, pp. 67–79.
Lehner, M., D. Jones, L. Yeomans, H. Mahmoud and K. Olchowska (2011) Re-examining the Khentkaues Town. In *Old Kingdom, New Perspectives: Egyptian Art and Archaeology 2750–2150 BC*, edited by N. Strudwick and H. Strudwick. Oxford: Oxbow Books, pp. 143–91. https://doi.org/10.2307/j.ctvh1dm4r.17
Lehner, M., M. Kamel and A. Tavares (2006) *Giza Plateau Mapping Project Season 2005 Preliminary Report*. Giza Occasional Papers 2. Cairo: Ancient Egypt Research Associates.
Lehner, M., M. Kamel and A. Tavares (2009a) *Giza Plateau Mapping Project Season 2004 Preliminary Report*. Boston: Ancient Egypt Research Associates.
Lehner, M., M. Kamel and A. Tavares (2009b) *Giza Plateau Mapping Project Seasons 2006–2007 Preliminary Report*. Boston: Ancient Egypt Research Associates.
Lehner, M. and F. Sadarangani (2007) Beds for bowabs in a pyramid city. In *The Archaeology and Art of Ancient Egypt: Essays in Honor of David O'Connor*, vol. 2, edited by Z. Hawass and J. Richards. Cairo: Supreme Council of Antiquities, pp. 59–81.
Lehner, M. and A. Tavares (2010) Walls, ways, and stratigraphy: signs of social control in an urban footprint at Giza. In *Cities and Urbanism in Ancient Egypt*, edited by M. Bietak, E. Czerny and I. Forstner-Müller. Vienna: Österreichischen Akademie der Wissenschaften, pp. 171–216.
Linant de Bellefonds, M.A. (1872–1873) *Mémoires sur les principaux travaux d'utilité publique exécutés en Égypte*. Paris: Arthus Bertrand Éditeur.
London Charter (2009) The London Charter for the computer-based visualisation of cultural heritage. In *Paradata and Transparency in Virtual Heritage*, edited by A. Bentkowska-Kafel, D. Denard and D. Baker. Farnham, UK: Ashgate, pp. 73–8.
Love, S. (2002) *Drill Cores Note Books*, 2 vols. Boston: Ancient Egypt Research Associates, field books on file.
Lutley, C. and J. Bunbury (2008) The Nile on the move. *Egyptian Archaeology* 32:3–5.
Montgomery, D.R. (2016) Emperor Yu's great flood. *Science* 353(6299):538–9. https://doi.org/10.1126/science.aah4040

Mubarak, A. (1887–1889) *Khitat al Tawfikiyya el-gidîda li-Misr el-Qahira wa-mudinha wa-bi-ladiha al-qadima wal-mashura*, vol. 19. Cairo: Bulaq.
Mutter, G.L. and B.P. Fishman (2017) Kafr, village of the pyramid sheiks. *Aeragram* 18(2):10–15.
Nolan, J. (2010) Mud Sealings and Fourth Dynasty Administration at Giza. PhD thesis, University of Chicago.
Nolan, J. (2011) On the cusp of a new dynasty. *Aeragram* 11(2):10–12.
Nolan, J. (2012) Fifth Dynasty renaissance at Giza. *Aeragram* 13(2):2–5.
Parsons, A. (1808) *Travels in Asia and Africa, Including a Journey from Scanderoon to Aleppo, and over the Desert to Baghdad and Bussora to Bombay, and along the Western Coast of India, a Voyage from Bombay to Mocha and Suez in the Red Sea, and a Journey from Suez to Cairo and Rosetta in Egypt*. London: Longman, Hurst, Rees, and Orme.
Petrie, W.M.F. (1883) *The Pyramids and Temples of Gizeh*. London: Field and Tuer.
Popper, W. (1951) *The Cairo Nilometer: Studies in Ibn Taghrî Birdi's Chronicles of Egypt*, vol. 1. Berkeley: University of California Press.
Posener-Kriéger, P. (1976) *Les archives du temple funéraire de Néferirkarê-kakaï (les papyrus d'Abousir): traduction et commentaire*, 2 vols. Bibliothèque d'Étude 65 (1–2). Cairo: Institut français d'archéologie orientale.
Redding, R. (2011) The OK Corral: Standing Wall Island mystery solved. *Aeragram* 12(1):2–5.
Reisner, G.A. (1931) *Mycerinus: The Temples of the Third Pyramid at Giza*. Cambridge, MA: Harvard University Press.
Reisner, G.A. (1942) *A History of the Giza Necropolis*, vol. 1. Cambridge, MA: Harvard University Press.
Richards, A. (1982) *Egypt's Agricultural Development, 1800–1980: Technical and Social Change*. Boulder, CO: Westview.
Said, R. (1981) *The Geological Evolution of the River Nile*. New York: Springer.
Said, R. (1993) *The River Nile: Geology, Hydrology and Utilization*. Oxford: Pergamon Press.
Saleh, A.A. (1974) Excavations around the Mycerinus Pyramid Complex. *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 30:131–54.
Sampsell, B. (2003) *A Traveler's Guide to the Geology of Egypt*. Cairo: American University in Cairo Press.
Sanders, D. (2012) More than pretty pictures of the past: an American perspective on virtual heritage. In *Paradata and Transparency in Virtual Heritage*, edited by A. Bentkowska-Kafel, D. Denard and D. Baker. Farnham, UK: Ashgate, pp. 37–56.
Seidlmayer, S.J. (2001) *Historische und moderne Nilstände: Untersuchungen zu den Pegelablesungen des Nils von der Frühzeit bis in die Gegenwart*. Berlin: Achet Verlag.
Sheehan, P. (2003) Brief encounters with the ancient landscape: urban archaeology in modern Cairo. In *Egyptology at the Dawn of the Twenty First Century*, vol. 1, edited by Z. Hawass. Cairo: American University in Cairo Press, pp. 455–60.
Sheehan, P. (2010) *Babylon of Egypt: The Archaeology of Old Cairo and the Origins of the City*. Cairo: American University in Cairo Press.
Somaglino, C. (2015) La navigation sur le Nil. Quelques réflexions autour d'ouvrage de J.P. Cooper, *The Medieval Nile. Route, Navigation and Landscape in Islamic Egypt*, Le Claire-New York, 2014. In B. Argémi and P. Tallet, *Entre Nil et Mers: La navigation en Égypte ancienne*. Nehet 3. Arles: Musée Départemental Arles Antique, pp. 123–61.
Spelterini, E. (1928) *Über den Wolken/Par-dessus les nuages.* Zürich: Brunner & Co.
Stadelmann, R. (1981) La ville de pyramide à l'ancien empire. *Revue d'Égyptologie* 33:67–77.
Stanley. J.-D. (2005) Submergence and burial of ancient coastal sites on the subsiding Nile Delta margin. Egypt. *Méditerranée* 104:65–73. https://doi.org/10.4000/mediterranee.2282

Stanley, D.J. and A.G. Warne (1993) Nile Delta: recent geological evolution and human impact. *Science* 260(5108):628–34. https://doi.org/10.1126/science.260.5108.628
Tallet, P. (2013) Note d'information: Les Papyrus de la Mer Rouge (Ouadi el-Jarf, Golfe de Suez). *Comptes Rendus de l'Académie des Inscriptions & Belles-Lettres* 2/2013:1015–24. https://doi.org/10.3406/crai.2009.92529
Tallet, P. (2016) Un aperçu de la région Memphite à la fin du règne de Chéops selon le 'journal de Merer'. In *Décrire, imaginer, construire l' espace. Toponymie égyptienne de l'Antiquité au Moyen Âge*, edited by S. Dhennin and C. Somaglino. Cairo: Institut française d'archéologie orientale, pp. 13–30.
Tallet P. (2017) *Les Papyrus de la mer Rouge,* vol 1: *Le journal de Merer' (Papyrus Jarf A et B).* MIFAO 136. Cairo: Institut française d'archéologie orientale.
Toussoun, O. (1925) *Mémoire sur l'histoire du Nil.* MIFAO 8–10. Cairo: Institut française d'archéologie orientale.
Wagner, G. (1935) Geologische Beobachtungen an den Pyramiden. *Aus der Heimat* 48:19–21.
Willcocks, W. (1889) *Egyptian Irrigation*. London: Spon.
Willcocks, W. (1903) *The Restoration of the Ancient Irrigation Works on the Tigris, or the Re-Creation of Chaldea*. Cairo: National Printing Department.
Willcocks, W. and J.I. Craig (1913) *Egyptian Irrigation*, 2 vols. 3rd edn. London: Spon.
Witsell, A. (2018) Kromer 2018: basket by basket. *Aeragram* 19(1):2–9.
Wu, Q., Z. Zhao, L. Liu, D.E. Granger, H. Wang, D.J. Cohen, X. Wu, M. Ye, O. Bar-Yosef, B. Lu, J. Zhang, P. Zhang, D. Yuan, W. Qi, L. Cai, and S. Bai (2016) Outburst flood at 1920 BCE supports historicity of China's Great Flood and the Xia dynasty. *Science* 353(6299):579–82. https://doi.org/10.1126/science.aaf0842
Zibeluis, K. (1978) *Ägyptische Siedlungen nach Texten des alten Reiches*. Beihefte zum Tübinger Atlas des Vorderen Orients 19. Wiesbaden: Reichert.
Ziegler, C. (1999) Model of the Giza Plateau. In *Egyptian Art in the Age of the Pyramids*, edited by D. Arnold, K. Grymski and C. Ziegler. New York: Metropolitan Museum of Art, pp. 214–15.

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