

Surveying in Ancient Egypt

Joel F. PAULSON, USA

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SUMMARY

As many know from surveying textbooks, Egypt was the home of the first known surveyors. The textbooks explain how surveying was necessary in Ancient Egypt because the annual floods buried or destroyed boundary markers, which then had to be re-established for ownership of the fields. But surveying in Ancient Egypt went beyond re-establishing boundaries. Scribed control marks on the pyramids, architectural markings in tombs, and a few surviving sketch plans of tombs and shrines show that surveyors also performed construction surveys.

Scribes, the educated professional class in Ancient Egypt, had the practical and mathematical knowledge to supervise surveys. These scribes saw themselves as a special class of people who maintained order in society by running the bureaucracy. The symmetry and proportion of the monuments of Egypt well attest to the skills of these ancient surveyors.

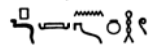
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For the purposes of this paper, Ancient Egypt will be considered as the time from the earliest inhabitants of the Nile Valley down to the conquest of Egypt by Alexander the Great in 332 B.C.E. From the earliest times, the Egyptians had developed a system of land ownership, land measurement, and the mathematics to deal with these measurements. These systems did not, of course, end with the conquest of Alexander, but at that point in history, the intellectual knowledge of Egypt became intertwined with the Hellenistic systems. Because the ruling class was Greek, they could impose many of their mathematical and taxation methods onto Egypt as a whole, though even the Greeks recognized the earlier Egyptian influences on their sciences and mathematics, so the influences went in both directions.





For some of the Egyptian words and phrases, I will be showing the hieroglyphics and a rough modern transliteration into the consonantal values. Keep in mind that the Egyptians did not write vowels as part of their words, so the consonants are generally strung together using an “e” sound between them so that we can at least pronounce them approximately.

The Egyptian phrase for a surveyor was a “rope stretcher” and surveying was known as “stretching a rope”

 (pd nwh)

In fact, a calibrated rope was one of the tools used in surveying. Several tombs from the New Kingdom era, about 1100 BCE show the tomb owner overseeing men using ropes to measure fields, presumably to calculate the taxes for yield of these fields.

The Egyptians developed a system of measurements based on a natural device, i.e. the human arm. They used cubits, traditionally the length from the bent elbow to the tips of the fingers; palms, the width of the palm of the hand; and digits, the width of the human fingers. So four digits equals one palm and seven palms equals one cubit. In hieroglyphic form, they look like this:

	(mh) cubit
	(šst) palm (of hand)
	(db’) digits (fingers)
	(kht) rod (100 cubits)

Many Egyptologists have tried to define the length of a cubit, and have arrived at several approximations. For the purposes of this paper, I use the length used by Howard Carter in his work in the Valley of the Kings of one cubit equals 0.5231 meters, or for those of us from a more primitive society, one cubit equals 20.59 inches. One of the biggest problems with arriving at a definite value for the cubit seems to be that a number of “cubit sticks” have survived from Ancient Egypt, but they all are of different lengths. Some archaeologists have

referred to most of them as “ceremonial” because of their high degree of decoration, and to account for their lack of standardization. But Egypt has a long history. As much time went by between the building of the pyramids and the conquest of Alexander the Great, as has gone by between the time of Jesus and our own times. During these periods there could have been many revisions to the length of the cubit, if there ever were a standard established.

The Egyptians also had measures of area, the most common one being the $\overline{\text{I}}$ or $\overline{\text{II}}$, (setat) which was one square khet, or 10,000 square cubits. This comes out to approximately 2,735 square meters or 2/3 acres (Gardiner, 200). This was the standard measurement for agricultural fields.

The surveying tools that the Ancient Egyptians used was simple, but, as we will see, they used them quite effectively. The most basic tools were the plumb bob, a cubit rod, for short measurements and a calibrated rope of 100 cubits for longer measurements. These ropes were sometimes knotted at intervals. In spite of the claims of some web sites, the Egyptians do not appear to have been acquainted with the Pythagorean theorem as a mathematical principal. However, they do seem to have used its practical application of the 3-4-5 triangle for establishing 90 degree angles. For leveling, the Egyptians used a tool shaped like the letter “A”. A plumb bob, hanging from the top of the “A” would hang through the center of the cross beam when the tool was level from end to end. For larger scale leveling, it is speculated that they would use channels or wooden troughs filled with water, though none of these have survived. For maintaining a straight line, the Egyptians might have used a “merkhet”, which was well-known from later Graeco-Roman times. The “merkhet” consisted of a fixed plumb bob on a holder. This plumb bob would be aligned with a staff having a cleft in it, or something as simple as the “center-rib of a palm leaf as a sight vane” (Lyons, 135).

Surveying the fields was very important to the Ancient Egyptians. Ownership of property was common, though most of the land was owned by the pharaoh or the temples. This, of course, made the surveying even more important, because rents and taxes on property were based on the area being farmed.

In the New Kingdom, several noblemen who owned tombs in the private cemetery on the west bank of Thebes, in an area known as Sheikh Abd el-Gurna, thought that their scribal duties and position as overseer of surveying of fields was worth depicting in their tombs. The most famous one is the Tomb of Menna (Theban Tomb 69). Menna was a “Scribe of Estate of the Pharaoh and Amon” in the mid-Eighteenth



Front Cordsman in a Scene of Stretching the Cord from the Tomb of Menna (Photo by David Goodman)



Rear Cordsman in a Scene of Stretching the Cord from the Tomb of Menna (Photo by David Goodman)

Dynasty (ca 1475 BCE). Part of Menna's duties would have been the overseeing of agriculture in the estates of the pharaoh, including the laying out or surveying of the fields. The scene of the stretching of the cord is part of an overall tomb plan showing the various phases of planting and harvesting of the crops for which Menna would have been responsible. The only instrument that is depicted in the scene is the rope itself. Nothing is shown about how they would maintain line, if that was important to this phase of the survey.

Another scribe from the same period, Djoserkareseneb also thought that his duties overseeing the surveying of the fields of the pharaoh was important enough to include in the scenes depicting his life and duties in his tomb. His tomb (TT 38) is also at Sheikh Abd el-Gurnah.

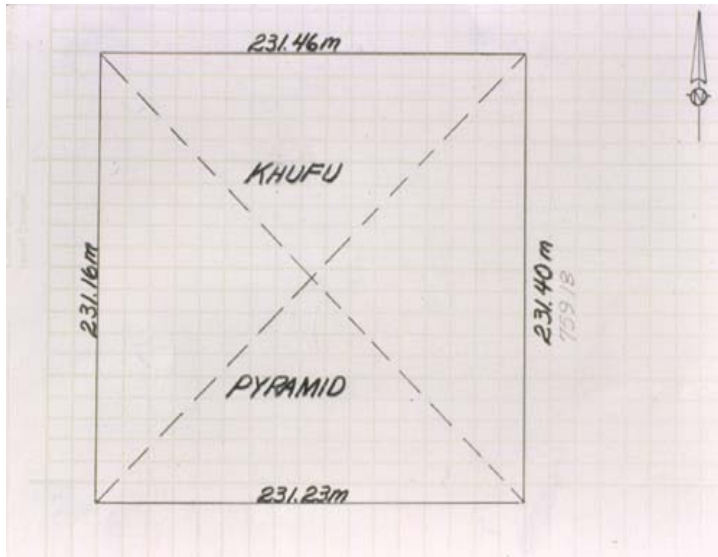
The other type of surveying done by the Egyptians was construction layout surveying. Royal tombs, including the pyramids, temples commissioned by the king, and probably palaces and other major structures would have been surveyed prior to construction. The "stretching of the cord" was a ceremonial laying out of the new structure. For important structures, even the pharaoh took part in the ceremony, playing the part of the chief surveyor. The most famous depiction of the ceremony comes from the temple of Edfu. Here the king is shown with the goddess Seshet, who is the personification of the art of writing and knowledge. Alongside the image is an inscription that reads, "I take the stake and I hold the handle of the mallet. I hold

the measuring cord with Seshet.” (Edwards, 259) So the king basically acts as a chainman in the ceremony. The king also took part in the celestial observations, at least ceremonially, to establish the alignment of structures. From the temple of Denderah comes another inscription that has the king “looking at the sky, observing the stars and turning his gaze towards the Great Bear.” (Edwards, 259) How much of a part the king really took in these activities is questionable, but he thought it worth taking credit for them.

Presumably, prior to surveying, plans would have been drawn for construction. Plans from Ancient Egypt are very rare, though some do exist, indicating that most structures probably had plans drawn for their construction. The scarcity of them today is probably because of the nature of papyrus on which plans would have been drawn. Papyri are rare, especially from the early periods, because it is destructible and simply has not survived. Almost certainly, only a very small percentage of the original body of literature, science, and other works by the Ancient Egyptians that was written on papyrus has survived. A few examples exist that were drawn or written on ostraca, pieces of limestone or potsherds, that were used for quick notes or sketches, almost like scratch paper.

The best known example of construction in Ancient Egypt is, of course, the great pyramid. No plans or specifications for the pyramid have survived, though certainly some probably existed at the time of construction. The pyramid of Khufu, built very early in Egyptian history, in the Fourth Dynasty, at about 2550 B.C.E., provides an excellent example of the kinds of accuracy that the Egyptian surveyors were able to achieve.

Several surveyors in the modern era have measured the great pyramid of Khufu and much speculation has been made from these measurements. Probably no structure on earth has been more written about. In the 1860’s an English surveyor, William Matthew Flinders Petrie, surveyed the great pyramid in an evident attempt to show that its measurements were related to the English system of measurement and that the pyramids had been built in feet and inches. Petrie evidently gave up on that idea and went on to become one of the foremost archaeologists in Egypt. More recently, the pyramid has been re-surveyed by David Goodman, working with the Giza Plateau project under the direction of Mark Lehner.

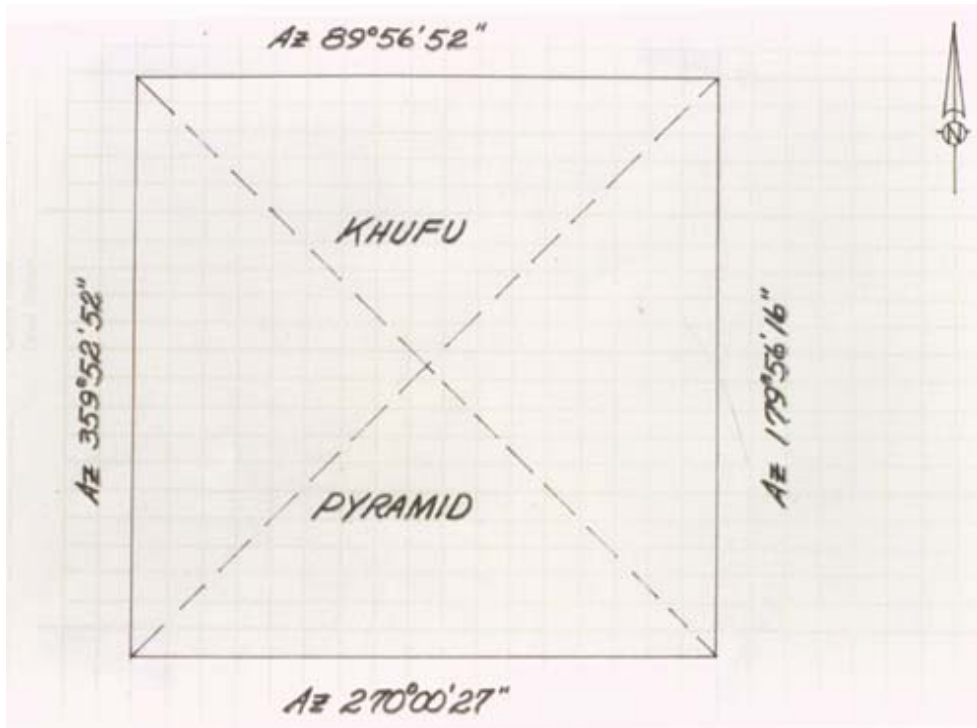


Measurements of Pyramid of Khufu

The great pyramid was originally encased in polished white limestone, but the outer casing was removed long ago for other construction projects. Therefore, the exact dimensions of the original limits cannot be determined with certainty. The measurements shown here are to the sockets as defined by Petrie. (Goodman, Personal Communication) For a structure that was 231 meters square, the largest discrepancy is 30cm between the north and west sides, but the difference between the north and east sides is only 6cm.

Again, the outer casings may have made up for some of these discrepancies.

The azimuths of the sides, are similarly accurate. David Goodman calculated the azimuths from observations of Polaris. The Egyptians obviously intended to align the pyramid with astronomic north, and with our best calculations, ephemeris and modern equipment, we could only improve on their observations by about 4 to 8 minutes of azimuth. Some of this difference could also be explained by a shift in the location of polar star relative to the earth, but that is beyond the scope of this discussion.



Azimuths of the Pyramid of Khufu

At the beginning of the construction of the pyramid, the priests, builders, and, perhaps, the pharaoh himself would have performed a “stretching of the cord” ceremony. How much of this was ceremonial and how much was practical surveying cannot be known. At some point, though, the foundation of the pyramid would have been marked out for construction. In addition, pyramids of princes, queens, and other family members were set out alongside the pharaoh’s. No one has yet found the original construction marks for the great pyramid, but ancient marks for one of the smaller queen’s pyramids adjacent to the great one have been found.



Pyramid of Khufu with Queens Pyramids



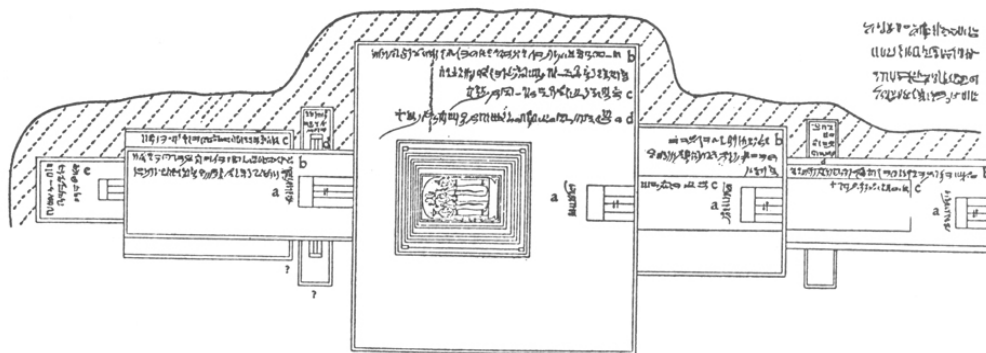
Ancient scribe marks for construction of Queens Pyramid
(Photos by David Goodman)

From a much later period, we have another example of construction. By the time of the New Kingdom of Egypt, between 1550 to 1070 B.C.E., for security and perhaps religious purposes, the pharaohs of Egypt had stopped building pyramids and instead built subterranean tombs on the west bank of Thebes in the Valley of the Kings. These tombs consisted of a series of shafts and chambers, with niches and side-chambers branching off these shafts and chambers.



Burial Chamber of Tomb of 20th Dynasty Tomb of Ramses IX

For one of these tombs, that of Ramses IV of the Twentieth Dynasty, we have one of the rare plans from ancient Egypt drawn on a piece of papyrus. Ramses IV, who reigned at approximately 1160 B.C.E., was a relatively minor pharaoh whose tomb in the Valley of the Kings is fairly typical of tombs from that dynasty. The tomb is decorated with vast religious scenery which aided the king in the afterlife, providing magical protection and guidance as he journeyed with the sun god and performed other godly duties in the netherworld. The plan of the tomb is on a papyrus now in the Turin Museum and lists the dimensions of the various shafts, chambers, and niches in the tomb.



The Turin Papyrus (From Weeks, 10)

The relationship of the measurements as shown on the papyrus and those measured in the tomb was first studied by Howard Carter and later by Kent Weeks of the Berkeley Theban Mapping Project (BTMP). (Weeks, 1979) In addition to the drawing on the recto (front) of the papyrus of the tomb with dimensions, the reverse side has additional measurements of another tomb, which likely is that of Ramses VI, also of the Twentieth Dynasty. When Weeks compared measurements between the papyrus and those taken by the BTMP, he used Carter's suggested value of the cubit of 1 cubit = 0.5231 meters. An example of the kind of results show a mix. For instance, in Chamber C, Weeks shows the following:

	BTMP Measurement	Turin Papyrus
Length	13.188m	13.078m
Width	3.14m	3.139m
Height	5.07m	5.006m (Weeks, 1979)

Other chambers and passages show similar results. Generally, the measured lengths were shorter than the planned lengths, but certainly they are close enough to show that Carter's value for the cubit is close to correct. Perhaps the workmen were skimping on the work a bit, or perhaps the approved as-built plans have disappeared over time. This example shows, though, that the Egyptians were capable of working with plans in construction and following the plans, underground as well as above ground.

Who the surveyors of Ancient Egypt were is not well understood. Almost certainly, the overseer of the surveyors would have been scribes, the bureaucrats of Ancient Egypt. The scribes were the educated professional class in Ancient Egypt, who had the practical and mathematical knowledge to supervise surveys. These scribes saw themselves as a special class of people who maintained order of society by running the bureaucracy. The stable, long-lasting order of Egyptian society and government is partially because of the guidance of these professionals.

But as scribes, these tomb owners would not just have managed the people who carried out the work in the fields and the surveyors. Scribes were the accountants, engineers and

surveyors. From an early age, scribes were taught not just how to read and write but also trained in accounting, geometry, and various other practical mathematics. Several papyri have survived which give examples of how the Egyptians would have solved mathematical problems. The Rhind Papyrus, now in the British Museum, is an example of one such papyrus. It dates from the Second Intermediate Period, about 1550 B.C.E, though the ancient copyist of the papyrus, a man named Ahmes, says that he copied the problems from earlier papyri.

The papyrus has examples of many kinds of problems, but the most interesting ones to surveyors are the geometry problems. The problems include calculating the area of pieces of lands that are circular (Problem No. 50), truncated triangles (Problem No. 52) as well as simple rectangles. Other problems involve calculating the slope of pyramids, though angular degrees as we know them did not exist. This was not an idle exercise, since one of the first pyramids to be built, the Meidum pyramid, evidently collapsed because the angle of construction was too steep.



Rhind Mathematical Papyrus

Using Problem 52 as an example, we can follow the logic and the steps that the Egyptian scribe would have used to solve a geometry problem. Remember, the *khet* is 100 cubits.

“Example of reckoning a truncated triangle of land. If it is said to thee, A Truncated triangle of land of 20 *khet* in its height, 6 *khet* in its base and 4 *khet* in the cut side. What is its acreage?

You are to combine its base with the cut side: result 10. You are to take a half of 10, namely 5, in order to give its rectangle. You are to multiply 20 five times, result 10 (*sic*). This is its area.

The doing as it occurs:

1	1000	/1	2000
½	500	2	4000
/4	8000		

Total 10000, making in land 20 (read 10)

This is its area in land.” (Peet, 94)

Peet, the interpreter of the papyrus goes on to note that in the second phase of the problem, the scribe automatically reduces quantities from the thousandths to account for the area compared to the square *khet*s. It is interesting to note, however, that this problem contains errors, as do other problems in the papyrus. Undoubtedly, the scribe felt that it was the example that was important, not the results.

The writing of the young scribes is filled with lessons (propaganda) about how important the work of the scribal class was. These lessons include harsh reminders about the miserable life of the cowherd in the marshes, the uncertainty of a soldier’s life, and how undesirable any occupation was, other than being a scribe. These young boys were indoctrinated into the system, but, as scribes, they could raise their lot and obtain the good life and death, complete with a tomb in the hills.

The grand monuments of Ancient Egypt bear witness to the capabilities of these ancient surveyors. A greater tribute to them lies in their part of a society that was able, with a few periods of breakdown, to maintain a cultural tradition that lasted for over three thousand years. In times of strength, the country was safe, stable and able to produce food surpluses. The monuments that we see today are merely the physical remains of that culture, but the Ancient Egyptians themselves realized that they had something special in their world.

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BIOGRAPHICAL NOTES

Joel F. Paulson is a licensed surveyor in the State of California, USA and has a M.A. in Egyptology from the University of California, Berkeley.

CONTACTS

Joel F. Paulson
988 Robin Court
San Marcos, California,
USA
Tel: +1-760-744-6031
Email: joelpaulson@sbcglobal.net