

2 Mohenjo-Daro, Indus Valley Civilization: Water Supply and Water Use in One of the Largest Bronze Age Cities of the Third Millennium BC¹

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INTRODUCTION

The beginning of the third millennium BC saw the first urban civilizations of the world formed, in the large river systems of the Euphratis–Tigris in Mesopotamia, the Nile in Egypt, and the Indus Valley in the northwestern Indian subcontinent. Mohenjo-Daro (Sindhi: “hill of the dead”), the probable capital of the Indus civilization, is one of the largest cities of the third millennium Bronze Age. What appear today as hills in the alluvial plain of the Indus, approximately 1 million square meters in area, seems to be only the “tip of an iceberg”. The major part of it has been covered by the alluvial silts of the river over the past 4,500 years. Out of the 1 million square meters of visible surface, 100,000 m² have been excavated so far, most of it between 1922 and 1936 by the Archaeological Survey of India (ASI) of the British Raj.

Discoveries by Mortimer Wheeler (Wheeler, 1968) in 1950, through deep soundings close to the western side of the “citadel”, gave clear indications that the ancient surroundings of the city were much lower than those of today. Over the past 4,500 years, the Indus seems to have silted up its valley—at least, close to Mohenjo-Daro—by more than 7 m. Recent drillings and further diggings have proved that a larger part of the city today is covered by the alluvium of the Indus. It is presently estimated that the major part of the city of another 3 million square meters is covered by the alluvium of the past 4,500 years.

In the 1920s, excavators were taken by surprise by the seeming homogeneity of the material culture and the architectural structures themselves, all being built in both burnt and unburnt bricks of today’s size and standards: approximately 6 × 12 × 24 cm (i.e. proportions 1:2:4). An exception was found in round cylindrical structures sunk vertically into the ground with diameters ranging from 60 cm to 2.4 m. Their circular “tubes” had once been formed by conically shaped bricks, allowing the construction of a perfectly built cylindrical form. Deep diggings inside the “tubes”

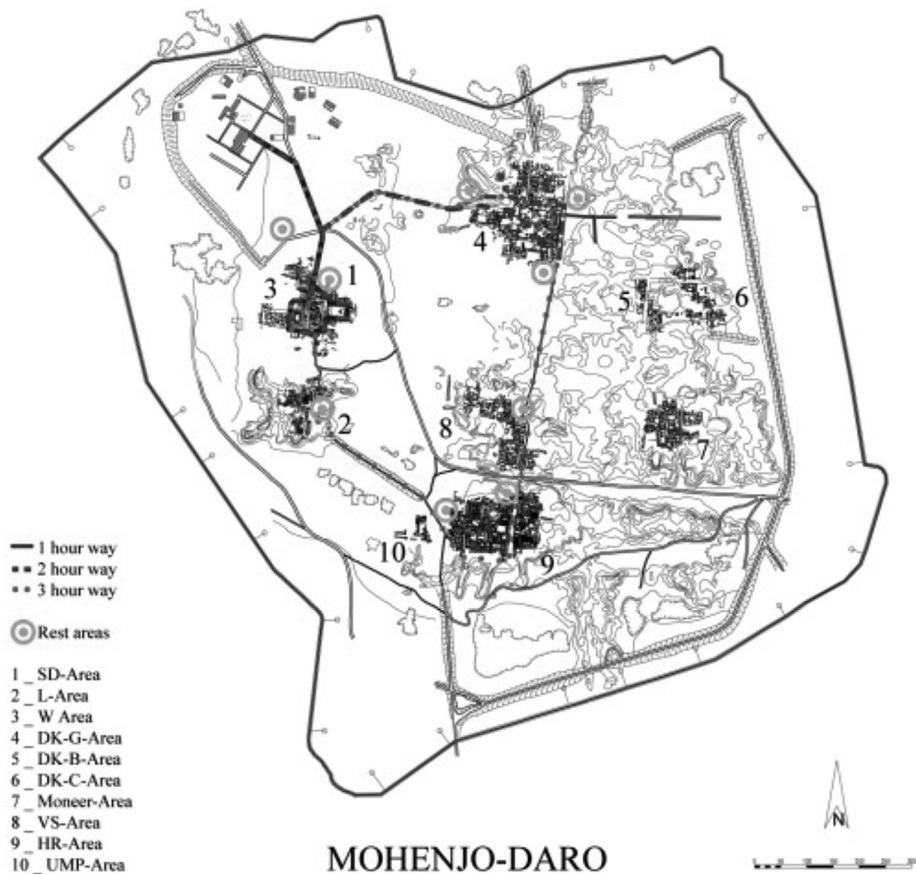


Figure 2.1. Site plan Mohenjo-Daro showing the excavated areas by name and visiting tours.

Source: © M. Jansen, Aachen Conservation Center.

by the author showed that these went down more than 18 m below the present surface. They were perfectly constructed wells for the vertical supply of water inside the city itself. It is estimated that more than 700 wells had existed at one time in the city of Mohenjo-Daro—the highest density ever found for a city worldwide, and the earliest one. In attempting to understand how these wells could have been constructed in a densely built urban context, it was concluded that either they must have been constructed bottom up, with the earliest strata of the settlement, or they were later sunk “top down” (German: *abteufen*), a technique that is still in use here and there in the villages of Sindh.

In the first case, the planning of the water supply must have coincided with the earliest planning of a city layout. In the second case, the digging of



Figure 2.2. The citadel mound with the so-called stupa from south, 1981.

Source: © M. Jansen.

the vertical shafts of the wells through many layers of occupation deposits must have been a crucial work.

WATER SUPPLY (WELLS)

As mentioned above, for the construction of the round well shafts, a special form of brick was developed. Corresponding to the smaller inside circumference of the shaft, these bricks were wedge-shaped. If such a vertically built cylinder made of wedge-shaped bricks were split down the middle and laid horizontally, the result would have been the first barrel vault, yet there is no evidence to show that the Harappans took this technological step forward. As far as we know, the corbelled vault was the only method they used to bridge larger spans using bricks, as attested by the roofing construction of drains and doorways.

Nevertheless, the cylindrical wells still stand as witnesses to the high standard of hydro-engineering attained by the Harappans, as their circular form is statically ideal for withstanding the lateral pressure exerted on the shafts, which were sunk to a depth of at least 20 m.

The cylindrical, brick-lined wells were probably invented by the Indus peoples of the alluvial plain. No wells have been found to date in any of the pre-Harappan or early Harappan settlement sites. Even in Mesopotamia

and Egypt, vertical water supply systems were virtually unknown within the settlements. It is all the more astonishing, therefore, that the radius of the mean catchment area supplied by each well in Mohenjo-Daro was calculated to be a mere 17 m.

In view of the tiny size of the rooms housing the wells, and the extraordinary shaft depth of more than 20 m, the only technically feasible manner of construction would be the “shaft sinking” method. This method has been employed up until recent times, and involves laying the first courses of bricks on a stout wooden ring set into the ground. The compressed earth is then removed from under the ring and the core forming inside it, while simultaneously the shaft is extended upwards. The result is that the growing brick cylinder gradually sinks down into the earth under its own weight, until water-bearing soil is reached. Whether this was really the construction method used by the Harappan well-builders awaits proof from further excavation in the near future.

An estimated 700 draw wells with an average catchment area radius of 17 m represented a frequency of wells; this is unparalleled in the history of water supply systems. The actual innovation in Mohenjo-Daro was the provision of a network of water supply points within the built-up urban area, from which water could be fetched conveniently as required, and then brought to the place of consumption (Jansen, 1991a: 17).

Wells on the “citadel”²

To date, only six wells have been located in the entire “citadel” sector, four in the SD Area and two in the L Area.

With an average catchment area of 3.175 m² per well, and an average distance of 56.3 m between wells, the SD Area figures are almost twice as high as the equivalent values for the Lower City. Even the average diameter of the wells here is almost twice that estimated for the Lower City. As a rule, the wells were accessible to the general public.

As far as location is concerned, convenience was not necessarily a deciding factor. Thus Block 1 in the SD Area, a complex building known as the “priests’ college”, does not have a single well, although the existence of several bathing platforms implies intensive use of water.

The corresponding values for the L Area regarding well density (every 56.5 m) and distribution pattern are similar. Generally speaking, the “citadel” area was, in its prime, the site of a number of imposing structural complexes. The “Great Bath” is undoubtedly the most outstanding of these today. Compared with the Lower City, water supply points in the form of wells are less frequent on average, but larger in diameter.

These and other indications weigh in favor of a public function for the wells in the “citadel” area. On the other hand, bathing platforms and effluent disposal drains are found just as densely distributed as in the Lower City.

In sum, these observations are interpreted as pointing towards the public nature of the functions performed on the “citadel”, possibly in connection with veneration rites, as posited by Marshall (1931) and Mackay (1938). It only remains to say that there is nothing in the archaeological record to date to justify Wheeler’s use of the term “citadel”, with its military connotations, for this section of the city.

Table 2.1. List of wells on “citadel”

<i>Location</i>	<i>Shape</i>	<i>Size (m)</i>	<i>Level (amsl) (m above msl)</i>	<i>Access point</i>
SD Area				
1. B1.6, R1725	Oval	1.85 × 1.30	54.86	From Main Street
2. B1.1, R1626	Round	2.07	51.24	Passage 12
3. B1.4, R1327	Round	1.77	51.03	Street?
4. B1.728	Oval ³	1.71 × 1.62	51.70	?
L Area ⁴				
1. Bl.C, R8530	Round	2.29	53.16	Street?
2. Bl.D, R8031	Round	1.78	54.47	Street?

Note: Mean diameter of wells in the SD Area and the L Area: 1.91 m.

Table 2.2. Wells in the DK-G Area⁵

<i>No.</i>	<i>Bl.</i>	<i>House</i>	<i>Room</i>	<i>Diameter (m)</i>	<i>Max. height⁶</i>	<i>Level</i>	<i>Ref.⁷</i>
1	1		19	0.85	−2.56	51.90	:50
2	1		20	0.85*	−2.01	52.46	:50
3	5		12	0.65	−3.96	50.50	:71
4	6		3	0.60	−2.59	51.87	:72
5	7		19	0.90*	−1.46	53.00	:77
6	7	VI	75	0.80	−2.53	51.94	:78
7	7	V	68, 77	0.90*	o.A.		:78
8	8	II	19	0.67	2.04	52.43	:87
9	8A		42	0.90	o.A.		:92
10	9	VI	78	0.80	−4.08	50.39	:95
11	10	II	26, 27	1.31	−1.58	52.89	:107
12	10	IV	87, 88	1.04	−2.56	51.90	:109
13	11		38	0.70*		o.A.	:119
14	11			0.80*		o.A.	:119
15	11			0.80*		o.A.	:119
16	12	V	95	0.90*	−2.44	53.57	:121
17	14	I	4	0.90	−2.44	52.02	:143
18	15	I	3	0.76	−2.22	52.25	:144
19	18		95	1.68	−0.02	54.45	:150
20	23		4	1.60*		o.A.	:154
21	24			1.04	1.16	53.30	:156

Note: Diameters marked * were measured at a later date. The mean diameter of the DK-G Area wells is 0.93 m.

Table 2.3. Wells in the VS Area

No.	Bl.	House	Room	Diameter (m)	Max. height (above amsl)	Source ⁸
VS-	A Area					
1		II	23	0.60*	52.94	:216
2		VIII	6	1.37	54.01	:218
3		XIII	61	0.60*	53.60	:219
4		XI	39	0.90	54.2	:221
5		XIX	22	0.60*	53.58	:223
6		XXII	5	1.10*	52.10	:225
7		XXXIII	4	0.90*	53.74	:231
8		XXXI	1	0.80*	49.15	:230
9		I	7.8	0.80*	52.84	
10		III	2	0.80*	54.18	

Note: Diameters marked *were measured at a later date. The mean diameter of the VS Area wells is 0.95 m.

Table 2.4. Wells in the HR Area

No.	Bl.	House	Room	Diameter ⁹ (m)	Max. height level ¹⁰ (above amsl)	Source ¹¹
HR-	A Area					
1	2	II	10	1.07	54.12	:179
2	2	III	18	0.95*	53.20	:180
3	3	VIII	6	0.90*	55.60	:182
4		IX	19	0.80*	53.08	:183
5		V	51	0.80*	54.04	:188
6		I	2	1.31m	52.75	:189
7		II	7	2.05m	53.93	:189
8		V	58	0.95*	55.20	:190
9		V	81	o.A.	53.28	
10		VI	26	0.75*	53.63	:192
11		VII	24	o.A.	55.00	
12		IX	88	o.A.	54.90	
13		XIV	11	0.50*	52.97	:199
14		XIV	11	0.50*	53.56	:199
15		XVI	38	0.75*	55.50	:200
16		XVIII	10	0.90*	55.14	:201
17		XXIII	6	1.07*	54.50	:202
18		XXIV	16	0.80*	55.00	:203
19		XXX	58	1.10*	53.72	:204
20		XLIII	103	0.80*	53.98	:205
21		XLVIII	1	0.60*	55.83	:206
22		XLIX	1	0.70*	55.25	:207
23		XLIX	6	0.90*	55.30	:207

Note: Diameters marked * were measured at a later date. The mean diameter of the HR Area wells is 0.91 m.

Table 2.5. Wells in the Moneer (MN) Area

No.	Bl. ¹²	House	Room	Diameter ¹³ (m)	Max. height (amsl)	Source ¹⁴
1	MN A	II	10	0.60*	55.02*	ARP
2		IV	3	0.80*	53.78*	ARP
3	MN B	IV	9	0.80*	53.80*	ARP
4	MN D	IV	2	0.70*	54.18*	ARP
5	MN E	II	5	1.00*	53.95*	ARP

Note: Diameters marked * were measured at a later date. The mean diameter of the Moneer Area wells is 0.78 m.

Table 2.6. Mean well density in individual excavated sectors

Excavated area	Surface area	Wells	m ² /well	Average freq. ¹⁵
"Citadel"				
SD	12.700	4	3.175	56.3 m
L	6.400	2	3.200	56.5 m
	19.100=	6	3.183	56.4 m
Lower City				
DK-G	28.000	21	1.333	36.5 m
DK-A,B,C	12.200	8 (10)	1.525 (1.220)	39.0 m (34.9)
VS	13.000	10	1.300	36.0 m
Moneer	7.200	5	1.440	38.0 m
HR	20.600	23	895	32.0 m
	71.000	67	1.060	33.3 m

As can be seen in the comparative chart in Table 2.6, in the Lower City the average area per well is 1.060 m², one-third of that of the "Citadel". Also, the mean diameter of the "Citadel" wells is 1.91 m, much wider than the one in the Lower City (which is below 1 m). If we assume a similar density of wells for the whole city and take the amount of 73 wells for 10 percent of the excavated area, we would have a hypothetical 730 wells for the conventional calculation of 100 ha for today's visible mounds above the present alluvium. Taking the hypothetical size of 300 ha (200 ha of which is buried under the alluvium), we would reach a total of 2,190 wells. No city in history has ever had even the smaller amount of 73 wells as proven by excavation, not to mention the hypothetical 2,190.

WATER USE AREAS

Almost every house in Mohenjo-Daro was equipped with a "bathroom". This consisted of a shallow basin or platform, approximately 1 m² in size, built of sharp-edged bricks which sloped towards an outlet connected to the street drain outside. Animal figurines retrieved from soakpits



Figure 2.3. *Left:* Aerial view of the citadel showing the Great Bath and the so-called stupa, 1982. *Right:* The Great Bath from north (top is south) with the Granary to the west and residential structures to the east. Aerial view from hot air balloon, 1982.

Sources: Both © M. Jansen.

incorporated in house drainage systems may suggest a ritual significance for these elaborate bathing facilities, which could not have served the interests of hygiene alone. This interpretation is also the obvious one for the first known swimming pool in history: the Great Bath of Mohenjo-Daro. Consisting of a rectangular brick basin with a capacity of 160 m^3 , and entered via a flight of steps at each narrow end, the Great Bath formed the center of an open inner courtyard enclosed within an imposing complex, some $1,800 \text{ m}^2$ in area. The very fact that such a large pool was installed within the city points towards a veneration of water in a way that is familiar from other early developed urban civilizations.

The city's effluent disposal system was the logical technological consequence of the townspeople's extraordinarily high consumption of water. In

the houses, bathing platforms and toilet outlets discharged into catchment vessels, which were often connected to the public drain network. Used water from the Great Bath was disposed of through an enormous drain 1.8 m high, big enough to walk through, and roofed with a corbelled vault.

Bathing and toilet facilities

For technical accomplishment and sheer numbers, the bathing platforms in Mohenjo-Daro were unique in the ancient world. Even in Mesopotamia, where the use of a standard brick as the smallest building element points to certain parallels with Harappa culture, such facilities were practically unknown. A typical bathing platform was installed inside the dwelling-house, either as a reserved area within a larger room or as a separate, custom-built “bathroom”. To allow for drainage, it consisted of a slightly raised, sloping platform floor built of several layers of bricks, laid in a staggered or criss-cross pattern, polished deep red from frequent use. The close-fitting, sharp-edged bricks were precisely formed in order to keep the joints as narrow as possible; these joints were grouted with clay mortar. The platform was edged in by an outside rim of standing bricks, creating a shallow basin. The platform floor sometimes sloped towards the middle of one side, but in most cases it sloped towards a corner where the effluent was guided either along a gutter or through a wall outlet, from where it discharged into the street drain outside or into a catchment vessel.

As a rule, such a bathing platform was installed against an outside wall to facilitate drainage by means of a direct connection to the municipal network. A toilet is often found incorporated into the outside wall of the platform, sometimes fitted with its own vertical chute for discharging the effluent into the street drain or cesspit. A pair of raised side brackets held a seat made of a longer brick or a wooden plank. However, other toilets were also found that consisted simply of a hole in the floor immediately above the effluent chute, in the manner still familiar in the area to this day.

The Great Bath in SD Area¹⁶

In 1925, a large complex covering approximately 1,800 m² was unearthed. It soon became known as the “Great Bath” after the sunken basin dominating its central courtyard (cf. Jansen, 1979: 105ff; Jansen, 1983).

It appears that the Great Bath was not conceived as part of the original structural concept for the “citadel”, but was built at a later date, as its colossal effluent drain cuts diagonally across the northeastern corner of the lower and older section of the “granary” adjoining the Great Bath on

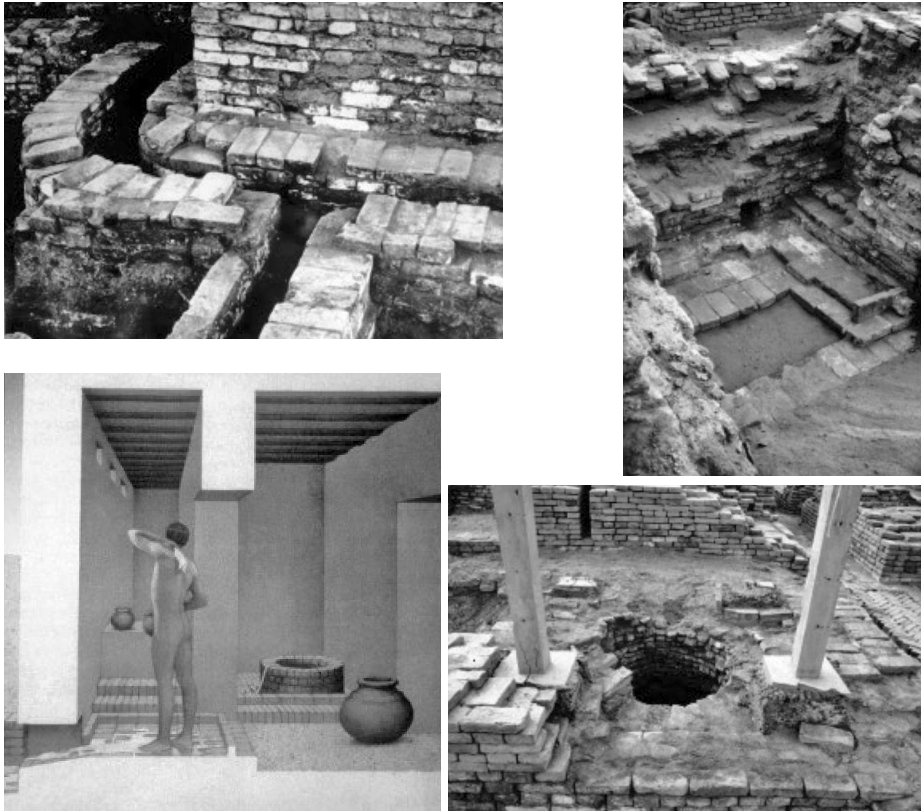


Figure 2.4. *Top left:* A curved brick drain after excavation in DK-G Area, 1927. *Top right:* Bathing platform with water outlet to street in Moneer Area after cleaning, 1982. *Bottom left:* Reconstruction of a bathing platform with attached well and drain to the street. *Bottom right:* Brick lined well in HR B, badly damaged, 1979.

Sources: *Top left:* copy from original, M. Jansen. *Top right:* © M. Jansen. *Bottom left:* des.R. Bunse, © M. Jansen. *Bottom right:* © M. Jansen.

the west. Furthermore, the technical construction of the tank-like basin with an outer retaining wall and inner bulkhead-type props indicates that it was sunken into older construction layers. The outer retaining walls, up to 2 m thick and at the inner side inclining by 8°, are built in English bond and taper upwards. Originally, a public street up to 5 m wide ran round the perimeter of the complex and set it apart from neighboring structures, thus making the Great Bath the only known freestanding, detached single building in Mohenjo-Daro. This walkway was largely blocked by structures superimposed at a later date, when alterations were also carried out to the interior of the complex.

The heart of the complex was a rectangular tank measuring approximately 12 m by 7 m and 2.4 m deep, to which two flights of ten steps

each led down: one flight at the northern end and one at the southern end. From the south, the pool courtyard was entered through a surrounding colonnaded gallery, its pillars set at intervals of two-pillar widths. Two entrances in the south of the complex led into a narthex-like anteroom, and from there through nonaligned passages to the gallery and the pool courtyard. From here, further rooms to the east and north could be reached. In all, three concentric walkways enclosed and provided access to the central basin. The innermost ran round its perimeter inside the courtyard, the middle one was the colonnaded gallery itself, and the third was the public street marking the outside boundary of the entire complex. Such a layout, with the pool as its centerpiece, begs the question of ritual processions, or at least of the possibility that the concentric walkways did not serve solely as access routes.

A pillared hall, partly blocked up at a later date, once faced the entire northern side of the pool courtyard. But neither here nor elsewhere could any material evidence be produced in support of a posited cult function for the Great Bath complex. Apparently the Great Bath was supplied with fresh water from a large, double-walled well that was built of wedge-shaped bricks; this well was located in one of the compartments to the east. The top of the well shaft was 51.24 m (168'1") above amsl and served as the benchmark level for the SD Area. A second tube built of standard bricks was laid 33 cm outside the first one as original lining of the well, supporting the hypothesis of a late construction of the whole setting.

There is reason to doubt whether the basin with its capacity of 150 m³ was filled by hand, especially as the Indus people were familiar with hydraulic principles. Nevertheless, no trace of any aqueduct-type facility could be ascertained. Just how sophisticated their leveling technique must have been is shown by the basin floor, which inclined towards the effluent outlet in its southwestern corner with a gradient of 1.4–1.7 percent. This rectangular outlet of 391 cm² (17 cm high × 23 cm broad; cf. Marshall, 1931: 131) at 49.02 m above MSL discharged the used water into a channel (50 cm broad, 10 cm deep), which traversed an underground chamber (6.8 m E–W, 1.73 m N–S) that could be entered from above. From here the effluent flowed into a drain 73 cm broad, which was roofed over with a corbelled vault 2.07 m high. The difference in level between the basin outlet and the point where the corbelled drain breaks off at a distance of approximately 18 m was 0.33 m, the equivalent of a gradient of about 1.8 percent. The extraordinary height of this mighty drain may have been necessitated by the difference in level between that of the bottom of the drain (in turn predetermined by the depth of the basin) and that of the surface of the public street around the outside perimeter of the complex.¹⁷ Running west first, the drain then turned north and then west again, thereby cutting diagonally across the northeastern corner of the lower basis of the “granary”. After a few meters running west towards the western edge of the “citadel”, the drain was discontinued. Later, in his excavation in

1950, Wheeler discovered the obvious continuation of the drain (only its floor) some 40 m further west. However, he did not recognize it as such (Jansen, 1986: pl. 82).

The tank construction of the pool is a technical masterpiece, an outstanding monument to Harappan engineering skills. Its 1.35 m thick inner “shell” was built of precisely formed bricks, laid so close-fittingly in stretcher bond that the joints were only a few millimeters wide. Remains of gypsum¹⁸ in the joints led to the assumption that the builders used gypsum mortar which is unlikely, as gypsum is not useful under water. For additional insulation, a 3 cm thick layer of bitumen was placed between this inner 1.35 m thick “shell” and another 0.3 m thick outer brick wall of lower quality. Often attested in Mesopotamia, this use of bitumen for waterproofing purposes in the Great Bath is the only known instance in the Indus civilization. As the Great Bath can be dated into the middle–late urban phase (around 2300 BC), it might coincide with the later appearance of the stone figures (priest king, kneeling figures, ram figures, etc.), also unique in the Indus civilization, which might indicate closer contacts with Western cultures. In turn, the sandwich tank construction was enclosed by an external wall which, as it also served as the foundations for the pillars of the surrounding gallery, was reinforced to the inner side with bulkhead-like buttresses to withstand lateral pressure. Presumably the ultimate function of this outermost retaining wall was to consolidate the actual foundation pit, sunk into older strata, before the freestanding, bitumen-sealed tank was installed inside. Finally, the remaining intervening gaps were filled in with stamped clay.

The Great Bath later underwent substantial alterations. To the north and west, the outermost concentric walkway was reduced to a narrow passage, while the inner colonnaded gallery was subdivided in such a way that it became impossible to walk around the pool.

The pillared hall adjoining the north side of the pool was blocked up and filled in, and used as a foundation base for an upper structure reached by a flight of steps. By this time, the chief functions for which the complex was originally designed seem to have been abandoned.

When it was excavated in 1925, the entire northwestern portion of the external wall, as well as most of the western row of pillars, was missing. The Great Bath as we know it today is in fact a hypothetical reconstruction in major parts, completed as early as 1927.

As in many other parts of the ruined city, remains of later overbuilding with associated Harappan artifacts¹⁹ were found among the deposits covering the Great Bath. Obviously this and the other large, non-domestic structures underwent changes of use in the post-urban period. This is taken as a further indication of the city’s loss of urban quality and, consequently, of the collapse of its municipal infrastructure. On the other hand, the presence of Harappan artifacts in the uppermost layers of deposits weighs in favor of the survival of the traditional crafts at least at local level,

and hence against the sudden, total abandonment of the settlement. In this regard it can no longer be determined, for instance, whether the destruction of the northwestern portion of the Great Bath revealed by the excavations in the 1920s dates to the Harappan period or whether it is of more recent origin—for example, the legacy of brick robbers or simply the result of erosion.

WATER SEWERAGE SYSTEM

Perhaps the most impressive engineering feat accomplished by the people of the Indus Civilization in Mohenjo-Daro over 4,500 years ago is the network of effluent drains built of brick masonry, which served as the city's sewerage system. The drains mostly ran along past the houses on one side of the generally unpaved streets, some 50 or 60 cm below street level.

U-shaped in cross-section, the sides and bottoms of the drains were built of bricks set in clay mortar, while the open top could be covered in various ways. Obviously the width of the open top was dictated by the dimensions of the covering bricks, which ranged from $25 \times 13 \times 5.75$ cm to $29.5 \times 14.6 \times 7.6$ cm. The drains built of the smallest size bricks vary in width from 17 to 25 cm and in depth from 15 to 50 cm—that is, the equivalent of between two and eight brick courses. Thus the drains range from 260 cm² to 1,200 cm² in cross-section. The loose roofing could be removed for cleaning as required.

The drains sloped at a gradient of about 2 cm per meter and met at varying levels, depending on cross-section and period. Constructions on curves were sited in such a way that frictional loss was minimized. Wherever a drain had to traverse a longer distance or several drains met, a brick cesspit was installed; this was the simplest method to avoid clogging caused by solids settling. The effluent flowed into such a brick shaft at a high level, filled it, then flowed out the other side at a slightly lower level. The suspended matter gradually formed a deposit which could be removed via steps leading down into the pit, which was likely covered by a loose wooden roof.

Besides the closed drains and cesspits for disposing of domestic effluent, open soakpits were also in common use, especially where small lanes opened onto bigger streets. They had to be cleaned of settled deposits from time to time. In places where the street drain was too far away from the houses, closed catchment vessels were installed instead. These were positioned under the vertical chutes on the outside walls and had to be tipped out regularly.

In some cases, they were fixed permanently into the walls so that their contents had to be scooped out. Other vessels had perforated bases and worked much like soakpits.

It was not unusual for the houses to be connected to the municipal sewerage system by means of individual branch drains, as the bathing and toilet facilities were generally situated on the street side of the houses where the effluent could flow straight down through a chute into the public drain or else into a catchment vessel. These built-in chutes very often stopped short some distance above the relevant drain or receptacle. In one instance (House 49, HR-B Area),²⁰ a vertical chute serving two toilets ended thus, which must anticipate the original existence of at least one upper storey. Occasionally, vertical pottery drainpipes, formed of stacks of close-fitting, conical sockets approximately 60 cm long, were built into outside walls to discharge effluent from the roof or the floor above. The noxious smells emitted by the effluent chutes, soakpits, cesspits, and drains must have been a serious public nuisance, which could only have been alleviated somewhat by a constant high rate of flow and regular cleaning. Both measures must have implied a large workforce engaged in fetching water for flushing and in clearing out deposits.

Analysis of effluent disposal facilities in the DK-G Area²¹

The DK-G south Area

The excavators marked out this sector into 12 structural complexes (blocks), based on surface evidence of brick walls. In digging deeper, further subdivisions of the sectors were made based on identified streets and lanes. For identification purposes, each block was divided into houses



Figure 2.5. Excavated well in DK-G south Area.

and each house into rooms, so that even the smallest compartment can be located.²²

The following analysis of the effluent disposal system is based on the five horizontal section plans of the southern DK-G Area published by Ernest Mackay in 1938. These plans show the structural situation at the respective development phases corresponding to the selected levels. Studied together with the accompanying detailed descriptions, these section plans provide us with a three-dimensional reconstruction of the development of the drain network. This illustrates not only the changes down through time, but also, at least in part, the anticipated revision of the excavators' site chronology.

Flow capacity estimates

The first attempt to calculate the volume of effluent discharged by the drains was carried out in 1977.²³ For this test, the drain network of Intermediate II Phase was selected. However, it was not possible to calculate the flow capacity of an interconnected network, as none was found completely intact. As a result, the aim of the investigation—namely to establish by means of capacity calculation whether the system discharged mixed or separated effluent—could not be achieved. In all probability, the drain network served principally to dispose of domestic effluent from the buildings. No evidence of any kind was found that the drains had also served to channel off rainwater from the streets and other public places which, significantly, were left unpaved. Apparently rainwater was simply allowed to seep into the silty ground. In the semi-arid climate²⁴ of the region, with its brief but dramatic seasonal downpours, this must have turned the city into a sea of mud.²⁵ Only in First Street, at a depth of 18' below the surface, did the excavators encounter indications of a form of street paving consisting of brick and pottery fragments. Ultimately, it may have been the nature of the extremely fine-grained, dense alluvial silt that inspired the Harappans to devise this sewerage system to channel off the everyday household effluent in such a densely populated city as Mohenjo-Daro. Once this was developed, they then installed similar systems in other settlements, so that an effluent drain network has become a characteristic feature of the urban period of the Indus civilization. The dimensions of the drains do not seem to comply with any rational considerations, but rather to have been dictated by the material and construction norms that were then current. Thus, while rarely exceeding 25 cm in width, the drains vary greatly in depth, and it was this latter factor that determined their effluent volume capacity. No doubt the width was fixed by the standard brick length, as only a cover formed of single bricks spanning the entire width would have been adequate to withstand flow pressure. Consequently, the rare examples known of drains wider than 25 cm required a different roof construction (e.g. the corbelled vault roofing the effluent drain of the Great Bath).

CONCLUDING REMARKS

The purpose of this analysis of the drain networks in the DK-G Area is, first and foremost, to give an account of the three-dimensional distribution of all the ascertainable hydraulic installations in this sector, thereby illustrating the high standard of water supply and effluent disposal services enjoyed at this early period (Early I Period). In addition, a description is given of the layers of drain networks installed in successive occupation levels which could provide the information necessary for a revised stratigraphy. Because of the absence to date of such a three-dimensional reference framework, it has not yet proved possible to revise the stratigraphy worked out by John Marshall (1931) and Ernest Mackay (1938). They based their stratigraphies on the mistaken (as is now known) assumption that the city as a whole grew horizontally layer by layer constantly, and not, as is customary today, on a comparative study of section profiles. Table 2.7 exemplifies the excavators' false "method" of dating structural remains and their associated finds on the basis of the data of similar heights.

The questioning of the traditional stratigraphic interpretation by Mackay (early intermediate, late) accepted to date means, of course, that all interpretations based on it become equally invalid. Consequently, we can make no detailed statements of any kind regarding the development of artifacts, etc., as their relative dating was based on the now rejected stratigraphy, unless we succeed in construing a "realistic" stratigraphy. As a rule, once an excavation has been completed, it is subsequently almost impossible to reinterpret its stratigraphic profile in any way other than that proclaimed by its excavator, because the only material preserved itself consists solely of

Table 2.7. A stratigraphical sequence of DKG in Mohenjo-Daro based on the (false) assumption of even growth in horizontal layers measured at thresholds, etc. (Mackay, 1938)

<i>Period</i>	<i>Pbase</i>	<i>Feet</i>	<i>Meters</i>	<i>Meters above MSL</i>
Benchmark				54.47
Late	Ia	+0.8	+0.24	54.71
Ib	−3.2	−0.98	53.49	
IIa	−5.0	−1.52	52.95	
IIb	−7.0	−2.13	52.34	
III	−9.9	−3.02	51.45	
Intermediate	I	−13.0	−3.96	50.51
II	−15.9	−4.84	49.99	
III	−20.4	−6.22	48.25	
Early	I	−24.0	−7.32	47.15 ²⁶
	II (assumed)			
	III (assumed)			

Note: The table showing the stratigraphic sequence of Mohenjo-Daro according to Mackay (1938: XIV–XV) with conversion of elevations from feet to meters by M. Jansen, including the calculation in amsl.

interpreted records, while the primary source context, the first-hand excavation in progress, no longer exists. In the case of Mohenjo-Daro, however, there is some hope that at least a rudimentary stratigraphy can be reconstructed. Here the drain networks come to our assistance, as they not only furnish us with telling insights into the highly developed urban infrastructure of the period, but also divulge significant chronological clues.

On the assumption that structures dating to a particular settlement phase were serviced by interconnecting drain networks—that is, the existence of the latter is an indication of the at least broad contemporaneity of the buildings thus linked—we investigated the drain situation in a selected area. Our choice fell on the drains exposed by the deep dig in the southern DK-G sector, as this is the only site where periodical alterations to the drain network can be proven archaeologically by means of vertical section profiles. A complete reconstruction of a revised stratigraphy of the DK-G Area would break the bounds of this attempt. In addition to an initial structural analysis, here barely outlined, such a reconstruction would entail an exhaustive investigation of the three-dimensional find distribution of the over 12,000 entries registered in the excavators' field books. Nevertheless, even the initial study produced enough evidence to show that a major revision of the relative chronology of individual structural clusters or blocks is indeed feasible. Over and beyond their former primary function of effluent disposal, therefore, the drain networks as connecting links between otherwise detached structural units may well prove indispensable for the archaeological reconstruction of the site stratigraphy. Here it must be repeated that the traditional classification of the occupation periods (or levels) (e.g. "Late I–III" or "Intermediate I–III") no longer has any stratigraphical significance whatsoever—apart from the absolute elevations given in Table 2.7. Consequently, Mackay's "horizontal section plans" (Mackay, 1938: pls. 101–6), far from corresponding to actual stages in the construction of the city as he believed, represent nothing but horizontal cross-sections at the respective depths. A more realistic stratigraphy based on all data available is feasible.

NOTES

- 1 Major parts of this text have been taken from Jansen (1993).
- 2 The name "citadel" was introduced by Wheeler (1968), having induced the idea of a "priest-king" political system with an elite reigning on the "citadel". It hosts the following excavations: Banerjii's excavation, SD Area (after Siddiqui), L Area (Mackay), REM Area (after R. E. M. Wheeler).
- 3 This well is oval only in its upper portion, presumably due to lateral pressure from the surrounding soil. The lower portion measures 1.7 m in diameter. The Research Project Mohenjo-Daro carried out a deep excavation in this well in 1986.

- 4 The L Area was excavated in 1927 by Ernest Mackay. Why it was named "L" is unknown.
- 5 The DK Area was named after the excavator K. N. Dikshit. The DK-G Area, however, was excavated after 1927 by Ernest Mackay (Mackay, 1938).
- 6 The elevations refer to the benchmark level of 178' 7" above msl (=54.47 m above msl) as marked in Block 9, House I, Room 27. Cf. Mackay (1938: XIV).
- 7 Cf. Mackay (1938).
- 8 Marshall (1931).
- 9 In the excavator's report (Marshall, 1931), almost no reference is made to the diameter of the wells. The figures marked * were taken from the site documentation of the Research Project Mohenjo-Daro.
- 10 Likewise omitted from the excavation records are absolute elevation figures. When given, they are "below surface", so that they are unusable for our purpose. The height measurements given have also been borrowed from the leveling carried out by the Research Project Mohenjo-Daro.
- 11 Marshall (1931).
- 12 This Block/House/Room terminology for the structures excavated in the Moneer Area was introduced by the Research Project Mohenjo-Daro; the excavators' original terminology, preserved only in the field book entries, cannot be reconstructed.
- 13 The figures marked * were taken from the site documentation of the Research Project Mohenjo-Daro.
- 14 Aachen Research Project.
- 15 Calculated as the root of the average catchment area, which is measured as a square.
- 16 The SD Area was named after the archaeologist Siddiqui. The Great Bath was excavated by John Marshall himself.
- 17 Marshall speculated, because of its height, about the drain passage being an escape for men. The technical explanation seems to be much more reasonable.
- 18 This piece of information by the excavators is puzzling in view of the total unsuitability of gypsum mortar for water-bearing structures. Composition according to Marshall (1931: 132): gypsum 43.75 percent, lime 13.78 percent, sand 40.00 percent, alkaline salts 2.4 percent.
- 19 A sherd bearing a Brahmi inscription, unearthed during the clearing of the basin, was located in a secondary position. Cf. Jansen *et al.* (1983b).
- 20 The HR Area was named after H. Hargreaves, another archaeologist who excavated in Mohenjo-Daro between 1925 and 1927.
- 21 As mentioned in note 5, the DK-G Area, in the north of the lower city, was named after K. N. Dikshit, one of the early excavators. It was excavated from 1927 to 1931 by Ernest Mackay (Mackay, 1937). DK-G south is the only area in which deep digging (down to 6 m below the former surface) took place.
- 22 This horizontal orientation system differs from those normally used by archaeologists (e.g. grid/squares or coordinate points). The disadvantage of this system (as can be seen in the Moneer Area) is that if the reference system (map) is missing, an orientation is impossible.
- 23 Cf. Jansen (1977: 157). The capacity calculation was carried out by Herr Ucker, Koln, as part of a publication by the information service of the ceramics industry.

- 24 The climate of the region was probably damper during the peak Indus civilization period than it is today.
- 25 Even today, seasonal rains make Mohenjo-Daro and the surrounding countryside almost impassably muddy. Our campsite was swamped, and crates, books, and everything else on the ground was simply washed away.
- 26 It may come as a surprise that the lowest level in DK-G with 47.15 m amsl has the same height as the surrounding plain has, indicating that the “deep dig” by E. Mackay started from a hill. The deepest level of this dig did not reach lower than the surface of today’s plain outside the hill.

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