FINAL REPORT

August 1, 2007 – March 30, 2012

ARCE Groundwater Lowering Response Project, Luxor

"Monitoring of Groundwater and Ancient Structures in Luxor and Karnak Temples"

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ABBREVIATIONS

ARCE	- American Research Center in Egypt
EGYCO	- El-Naser Building & Construction Co.
FS	- Full Scale
GWLRP	- Groundwater Lowering Response Program
MSA	- Ministry of State for Antiquities Affairs
SIDA	- Swedish International Development Agency
SMT	- The monitoring survey company
SWECO	- Swedish Engineering Company
USAID	- United States Agency for International Development
ΔE	- Difference in the East – West coordinates
ΔN	- Difference in the North – South coordinates
AVG	- Average value (Mean)
STDV	- Standard Deviation

UNITS AND MEASURES

m	- meter
mm	- millimeter
m.a.s.l.	- meters above sea level

1 Introduction

This is the final report prepared by the *ARCE Groundwater Lowering Response Project* summarizing the results of ongoing structural and water level monitoring at the Luxor and Karnak temples. This report summarizes the monitoring results for the period from August 1, 2007 to March 30, 2012.

The monitoring results of the report period indicated no significant destabilization of the temple structures following startup of the dewatering systems at the two temples. Groundwater level measurements following dewatering systems startup showed the groundwater level fell to the design target levels originally proposed by the system's design engineers.

Structural monitoring is performed by the firm of SMT Consultants under contract to the MSA. Water level measurements are performed by ARCE staff with a subcontractor employed by the ARCE Luxor Project.

The following report describes the background of the dewatering project, the summary of the structural monitoring program, and a summary of the groundwater monitoring results obtained for almost five years period ending March 30, 2012 but the structural monitoring from September 2011 to March 2012 is not included due to the MSA taking over this monitoring responsibility.

2 Background

During the 1990s and up to 2006, high groundwater levels posed an increasing danger to ancient temples at Karnak and Luxor. Rising moisture and salt efflorescence in the foundation stones caused deterioration of sandstone masonry and inscribed walls.

The situation reached crisis proportions in recent years and in response, **USAID** initiated a groundwater-lowering project at the Karnak and Luxor temples in partnership with the MSA and the Swedish International Development Agency (SIDA). The project was designed and supervised by the Swedish company SWECO and was implemented by the Egyptian company EGYCO.

Following the construction of the groundwater lowering system a second "follow-on" project was initiated by **USAID** to help improve the condition of the temples and to pursue opportunities for conservation of antiquities. This second project, called the Luxor East Bank Groundwater Lowering Response Project (GWLRP), commenced on March 1, 2007.

3 Monitoring the Effects of Groundwater Lowering

The possibility of destabilization of temple structures as a result of dewatering was considered by SWECO during the design of the groundwater lowering system. Prior to the system construction, the groundwater levels at the temple sites normally had a seasonal groundwater level variation of 4.5 meters due to seasonal variation in the Nile River and local irrigation practices. (SWECO 2002: Salvation of Karnak and Luxor Temples, Final Report – Phase I). The designer concluded that past seasonal variations in the groundwater

level should have consolidated the clay and silt layers around the temple foundations. Therefore, the subsidence of foundations due to dewatering was considered a low probability.

According to the designer's groundwater simulation model the groundwater level would be reduced within the temple areas by an average of 2 meters after the startup of the groundwater drainage system. Ground movements were predicted to be a few millimeters. (SWECO 2002: Salvation of Karnak and Luxor Temples, Final Report – Phase I).

In consideration of the magnitude of possible damage which could occur if the temple foundations were destabilized by dewatering it was considered prudent by all parties that a program of structural monitoring be implemented. Even if the probability of temple destabilization was low, it was judged necessary that some form of monitoring of selected temple structures be implemented so that any destabilization would be detected to allow corrective action to be taken.

4 General Design of the Monitoring Program

The settlement-monitoring program includes a series of ongoing measurements intended to identify different types of movement of the temple structures. The measurements include: 1) Measurement of the elevation of structures to identify whether structures are sinking or rising, 2) Measurement of distance between a group of temple structures to see if the temple structures are shifting in any direction, and 3) Measurement of crack width and/or the tilting of temple columns. These three main types of measurements are described below:

- **"Precise-Level Measurement"** is a measurement of the precise vertical elevation (relative to sea level) of a point fixed on an ancient structure. (figure 1)

- **"Total-Station Measurement"** combines horizontal and vertical measurements between groups of temple structures. In this method, several survey measurements are made between locations visible from a reference survey point. The resulting geometry calculation tells the monitoring program whether any of the temple structures in the group has moved relative to the other objects. (figure 2)

- **"Crack and Tilt Measurements"** At selected places on temple structures special sensors are installed to measure the tilt of a position from the vertical (within a certain plane), or the width of a structural crack. At these selected locations, "tilt-meters" (figure 3) and "crack meters" (figure 4) were employed. The locations for these sensors were selected in consultation between archaeologists and the MSA.

Figure1 SMT staff measuring precise-elevations at the Second Pylon of Karnak.

Figure 2. SMT staff perform a total station measurement of Thutmosis Obelisk at Karnak temple

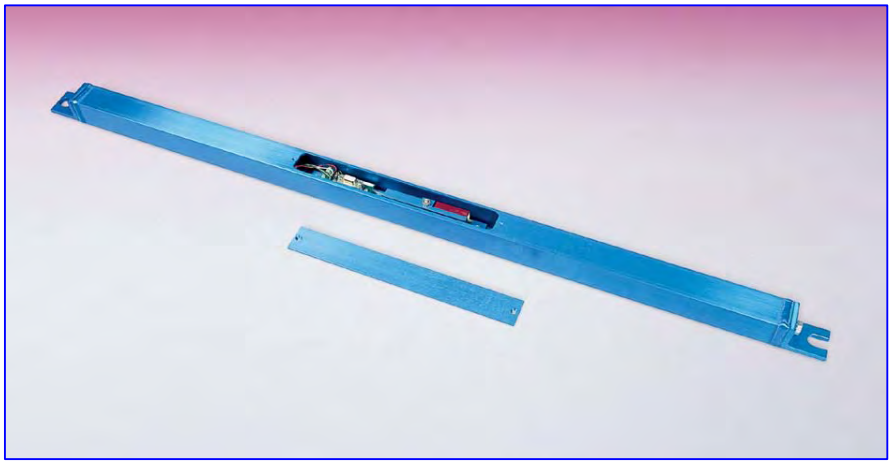


Figure 3 Tilt Sensor

The tilt meter is installed in a vertical or horizontal configuration. If the meter position changes even slightly the device generates an electrical signal proportional in size to the amount of movement. The signal from the meter is measured using a portable instrument that can be plugged into the tilt-meter with a cable. There are two tilt-meters installed at Karnak temple and two others installed at Luxor temple.

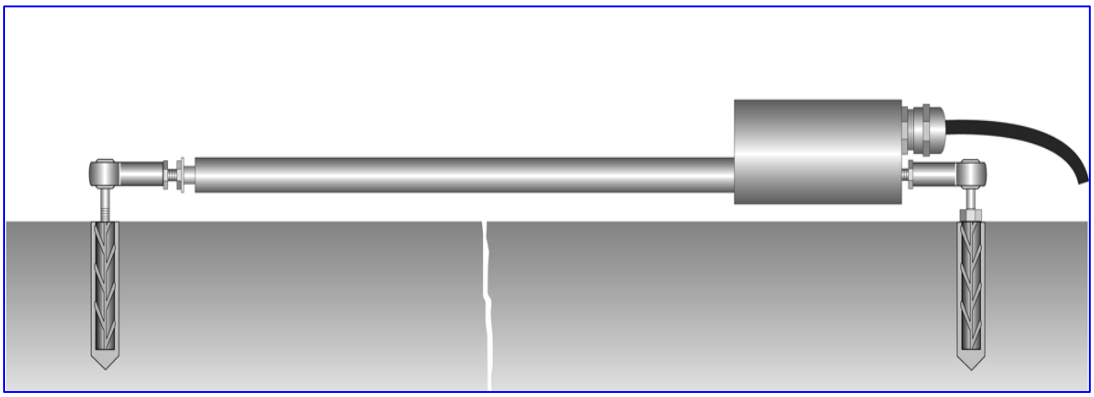


Figure 4 Illustration of the VW Crackmeter

The crack meter is an instrument that can be connected to either side of a structural crack. Any change in space between the bar connections generates an electrical signal measured using a portable instrument. There are three crack-meters installed at the Luxor temple and two crack-meters at the Karnak temple

- **Monitoring of Groundwater Levels**

In addition to monitoring settlement and structural movement, the monitoring program routinely measured water levels at observation wells (called "Piezometers") located within or near to the temple sites (Figures 5 and 6). Groundwater level measurements help determine whether the groundwater levels correspond to the system design. Water level measurements were suspended near the end of the construction phase in late 2006 and were re-started by the GWLRP in August 2007 at Luxor and Karnak temples.

Tables 1 and 2 show the top elevation (above sea level) of the piezometer pipes and provides a reference to their location on maps included in the accompanying appendices. These elevations correspond to the top edge of the piezometer pipes and are used for field measurement of groundwater levels.

These recently added locations - marked as K1, K2, and K3 in Table 1 below - allowed monitoring of the water level across the Karnak temple site from east to the west. In Luxor temple, one new measurement location is marked as "E". Point "A" near to the old police station was demolished, a new point marked as "A" was established inside Abu Al -Haggag mosque in an old roman well.

The levels are provided here for reference purposes.

Table 1 Top level of the piezometers at Karnak temple.

Piezometer Location	Identification Number	Elevation of top of pipe (meters above sea level)
A	201	77.71
B	106	77.66
C	111	77.24
D (missing)	117	77.37
E	125	76.46
F	128	77.17
G	133	77.34
H	234	78.38
I	229	77.05
J	207	77.50
Deep well	DW	75.64
K1	K1	73.97
K2	K2	74.39
K3	K3	75.34

Table 2 Top level of the piezometers at Luxor temple

Piezometer Location	Identification Number	Elevation of top of pipe (meters above sea level)
A	1	77.108 changed to 81.22
B	2	76.10
C	3	76.33
D	4	78.22
E	5	76.08 add to the monitoring system

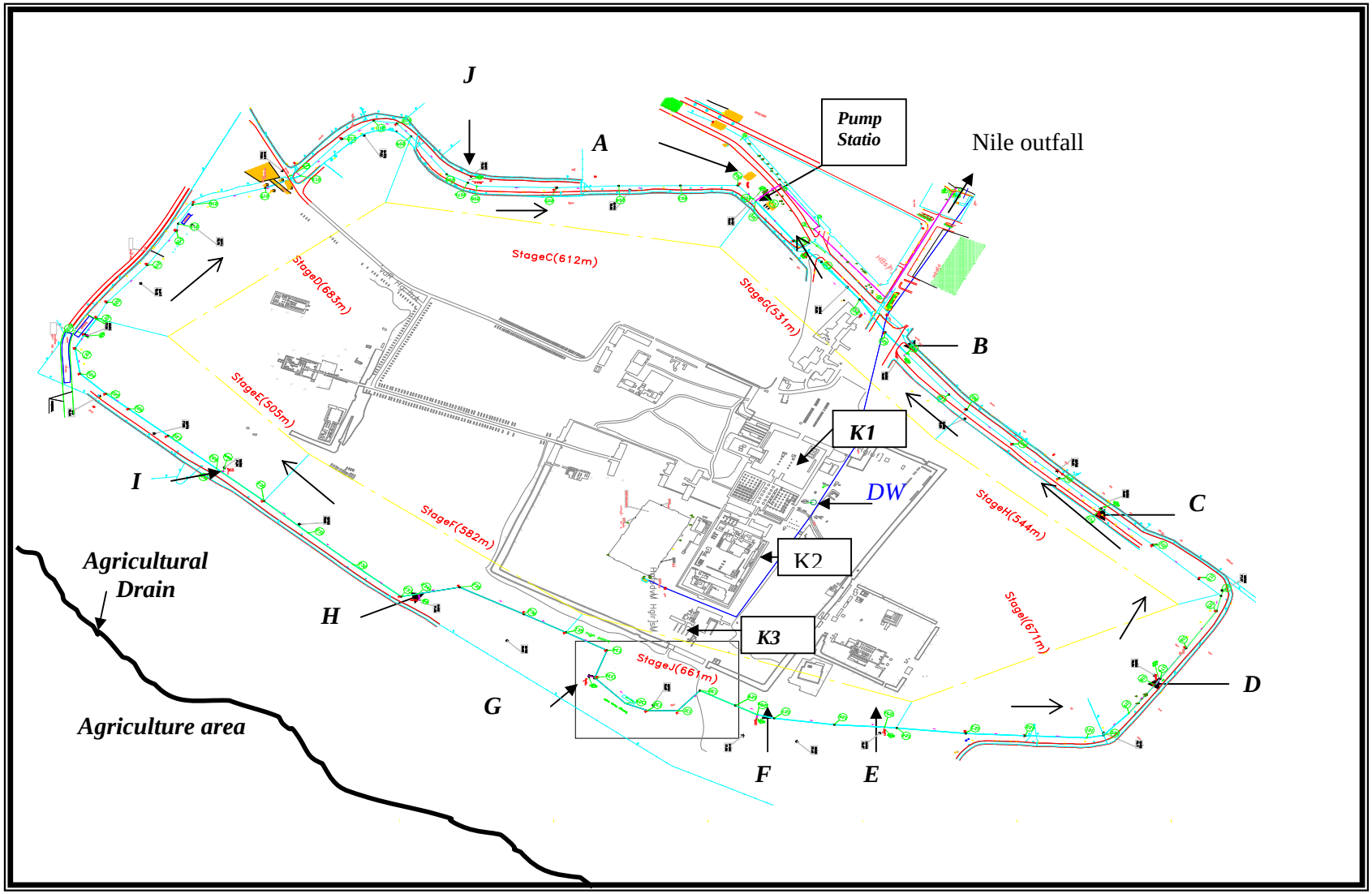


Figure 5 Groundwater piezometers and inspection wells at Karnak temple

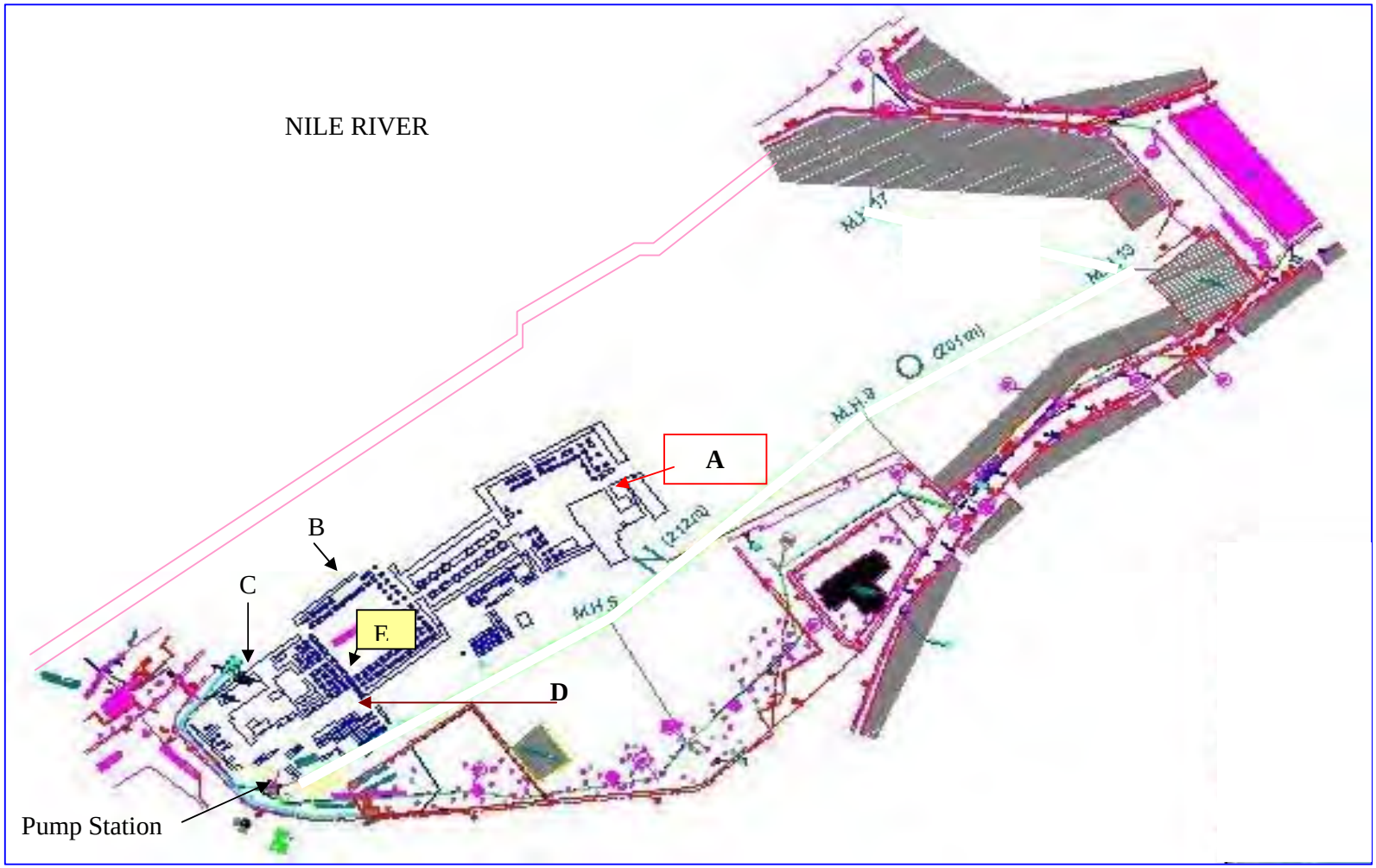


Figure 6 Groundwater piezometers and inspection wells at Luxor temple

5 Results and Discussion

The monitoring results from the subject-reporting period are summarized in the tables and graphs contained in this report for each of the two sites – the Karnak and Luxor Temples. The results are compared to the measurement tolerance limits to determine the significance of any detected movement.

1- Summary of groundwater monitoring data.
2- Summary of precise-level and total-station data.
3- Summary of crack-meter and tilt-meter data.
4- Summary of supplemental monitoring points.

5. 1 Results: Water level monitoring program

As a part of the monitoring program the average daily volume of water discharged from Luxor and Karnak pump stations is recorded (fig.7 and 8). During the report period, the average pumping rate was 6,336 m^3/day for the Luxor Temple and 12,761 m^3/day for the Karnak Temple. The pumping rate decreased by 33 % in winter season compared to the average rate in the summer months. This result corresponds to the seasonal changes in the Nile river level. The highest pumping rate was in July and August when the Nile is at its highest. Generally, **the discharge quantity decreased by about 60% by the end of the report period** (almost 5 years after starting the project)

Tables 3 and 4 summarize the Daily average flow from Luxor and Karnak groundwater pump stations as measured during the report period.

Table 3 Average, Max., and Min. water discharge at Luxor pump station

Date	Average	Maximum	Minimum
	m3/d	m3/d	m3/d
First year	8094	9687	6482
Second year	6640	7880	5508
Third year	5666	7064	4291
Forth year	5846	7166	4665
Fifth year	4983	6043	3939

Table 4 Average, Max., and Min. water discharge at Karnak pump station

Date	Average	Maximum	Minimum
	m3/d	m3/d	m3/d
First year	17058	19468	14490
Second year	13069	14720	11275
Third year	12422	15019	9444
Forth year	10616	12791	9072
Fifth year	9579	11941	7619

Fig 7. Luxor and Karnak pump stations Daily Flow

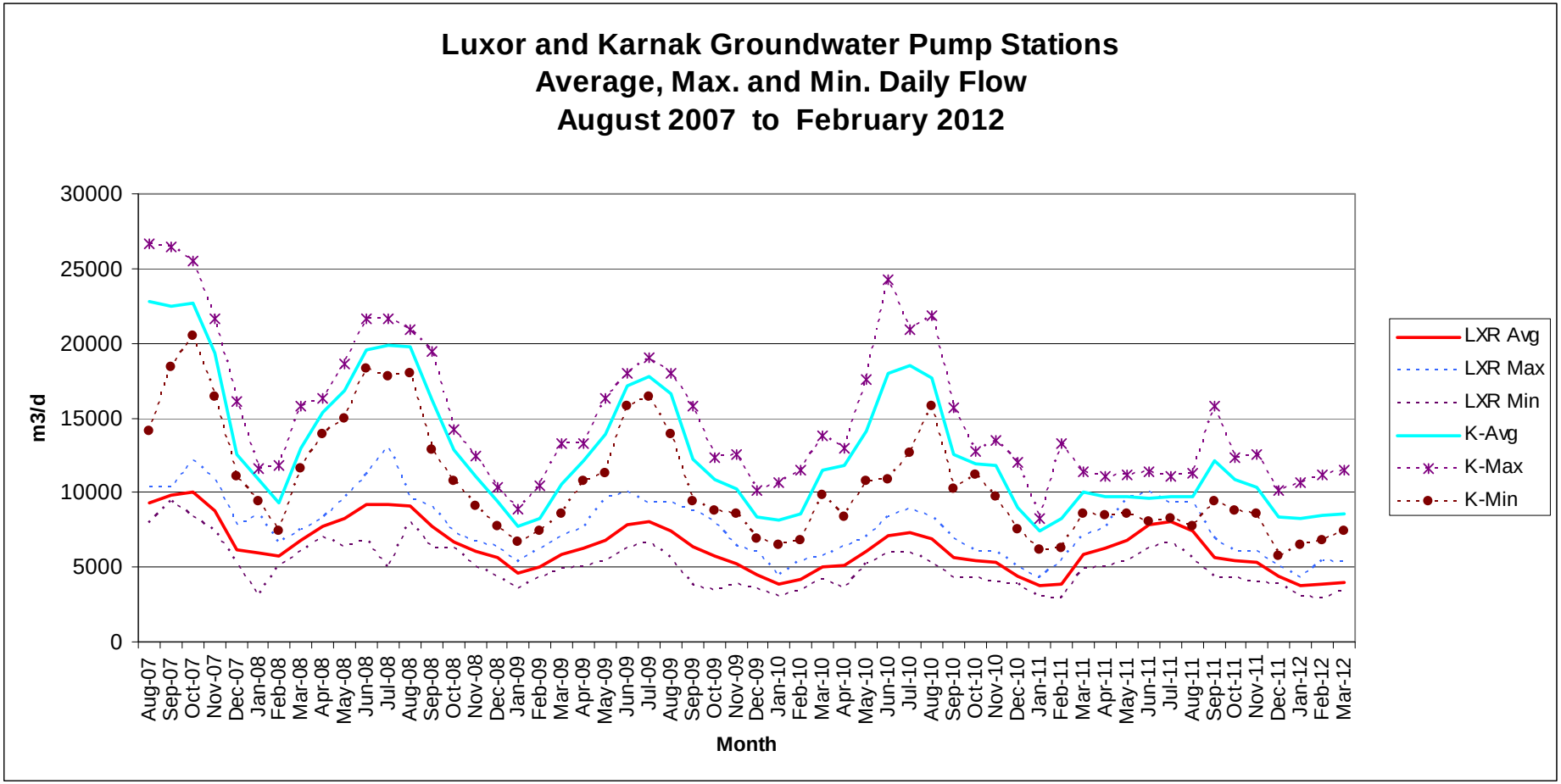
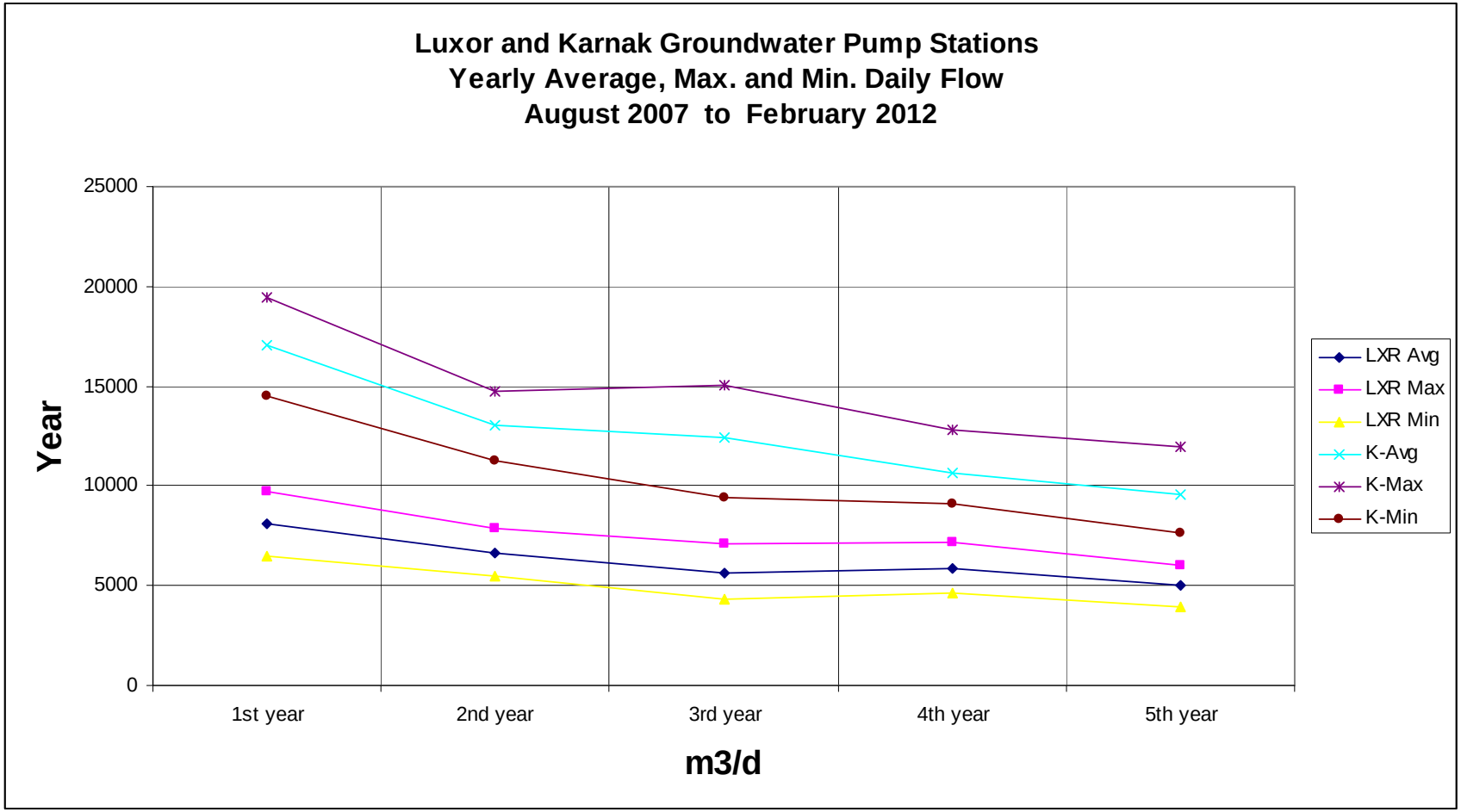


Fig 8. Luxor and Karnak pump stations average yearly flow



Around the Karnak temple, there are ten piezometers (also known as water level observation wells). Six of the wells are located on the southeast side of the temple - away from the Nile. These wells are numbered 201, 207, 234, 133 and 225, and are shown in figure 5. These wells show a relatively high groundwater level because they are located outside the collection system perimeter and are influenced by adjacent agricultural irrigation. The level of agricultural land beside a nearby agricultural drain canal is approximately 76.44 m.a.s.l. The lowest groundwater level at Karnak was observed in piezometer PZ-106 which is located inside the collection system.

An irrigation drain canal located about 200 meters to the east of piezometer PZ133 had a water level of 75.38 m.a.s.l., on November 6, 2007, which is approximately 3 meters above the Nile river level at Luxor. A litho-stratigraphic study of the general location of PZ133 - on the south-east side of the temple - (Kamel, 2003) shows a sandstone layer (Middle Pleistocene) between 64 to 56 m.a.s.l. which is characterized by high porosity and permeability. This zone may transport water towards the temple contributing to high water levels at the nearest piezometers, such as PZ133. The water level in PZ 133 appears related to the irrigation canal since the water level in the piezometer was lowest during February 2008 when the canal was emptied for annual maintenance. The water level in PZ133 later rose when the canal was refilled in the subsequent period.

At Luxor temple, the collection system intercepts groundwater flows from the city side of the temple, as shown in fig.6. The four piezometers at the Luxor temple are located in the Nile side of the temple and generally show a water level corresponding to the project target (<71.5 m.a.s.l.). Piezometer PZ-C shows the lowest groundwater level and the most variation in water level because it is located nearest to the deep well that contains a pump that is part of the dewatering system at the Luxor temple.

To date, the dewatering system has worked well and the measured groundwater levels have met the design groundwater target level in both Karnak and Luxor temples. No significant problems related either to system operation or structural destabilization has been observed during the monitoring period.

Tables 5 and 6 summarize the average water levels measured during the report period at Karnak and Luxor temples.

Table 5 Average water levels at Karnak temple(target <72.0 m.a.s.l)

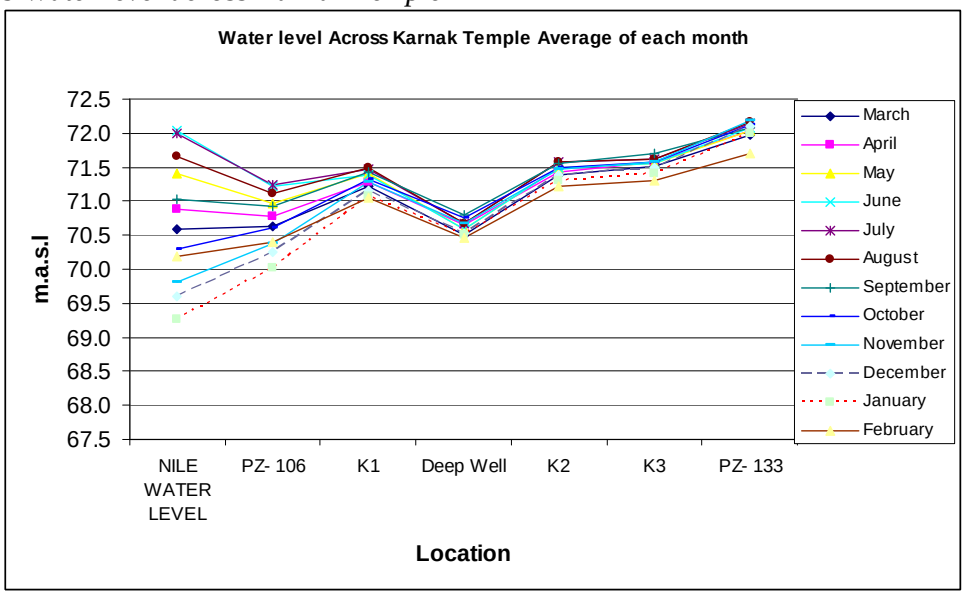
DATE	KARNAK TEMPLE								NILE WATER LEVEL
	PZ- 201	PZ- 106	PZ- 133	PZ- 229	K1	K2	K3	Deep Well	
	WL (m.a.s.l)	WL (m.a.s.l)	WL (m.a.s.l)	WL (m.a.s.l)	WL (m.a.s.l)	WL (m.a.s.l)	WL (m.a.s.l)	WL (m.a.s.l)	m.a.s.l
First year	71.5	70.6	72.1	72.4	70.9	71.3	71.5	70.5	70.3
Second year	71.3	70.5	72.1	72.4	70.9	71.3	71.5	70.4	70.3
Third year	71.4	70.3	72.2	72.4	71.0	70.6	71.5	70.5	69.9
Forth year	71.4	69.9	72.1	72.2	70.9	71.2	71.6	70.7	69.1
Fifth year	71.4	69.9	72.0	72.0	70.9	71.3	71.4	70.2	69.6

Table 6 Average water levels at Luxor temple (target < 71.5 m.a.s.l)

DATE	LUXOR TEMPLE					NILE WATER LEVEL
	PZ-A	PZ-B	PZ-C	PZ-D	PZ-E	
	WL (m.a.s.l.)	WL (m.a.s.l.)	WL (m.a.s.l.)	WL (m.a.s.l.)	WL (m.a.s.l)	m.a.s.l
First year	70.46	70.65	70.54	70.94	70.65	70.41
Second year	70.38	70.53	70.39	70.83	70.53	70.35
Third year	70.35	70.53	70.52	70.87	70.55	69.86
Forth year	70.28	70.39	70.46	70.69	70.50	69.10
Fifth year	70.20	70.36	70.39	70.68	70.39	69.56

The following graph represents the groundwater level across the Karnak temple using the new groundwater measurement locations K1, K2, and K3 established at the beginning of the subject reporting period.

Fig.9 Water level across Karnak Temple



5. 2 Results: Surveying and Elevation Measurements

Vertical and horizontal movements are monitored in several locations inside Karnak and Luxor temples using total-station and precise-level measurements. The measurements did not show a magnitude of movement greater than 3 mm. Movements less than 3 mm are not considered significant.

Tables 7 and 8 summarize the average, maximum and minimum values of the data collected during this report period. The collected data show that the measurements were within the instrumental reading error limits and that there has been no significant movement of major temple structures.

The monitoring of the monuments during the report period indicated that the monitored structures are stable; no significant vertical or horizontal movement has been observed.

Table 7 Average, maximum and minimum values of movement at Karnak Temple

	KARNAK TEMPLE – Difference in Level in (mm)																					
Points	**K1**	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**	**K9**	**K10**	**K11**	**K12**	**K13**	**K14**	**K15**	**K16**	**K17**	**K18**	**K19**	**K 20**	**K21**	**K22**	**K23**
Avg	0.04	-0.01	0.04	0.16	-0.12	0.10	0.08	-0.06	-0.09	-0.11	-0.12	-0.12	-0.11	-0.18	-0.13	0.07	-0.17	-0.21	-0.09		-0.20	-0.04	-0.12
Max	0.28	0.13	0.15	0.25	0.05	0.17	0.13	0.07	0.03	0.06	0.10	0.03	0.02	-0.05	-0.07	0.33	-0.07	-0.12	0.08		-0.14	0.15	-0.06
Min	-0.15	-0.31	-0.08	0.03	-0.24	0.02	0.00	-0.17	-0.22	-0.21	-0.28	-0.23	-0.23	-0.30	-0.21	-0.05	-0.26	-0.34	-0.21		-0.24	-0.23	-0.21

Table 8 Average, maximum and minimum values of movement at Luxor Temple

	LUXOR TEMPLE – Difference in Level in (mm)																						
Points	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**	**L11**	**L12**	**L13**	**L14**	**L15**	**L16**	**L17**	**L18**	**L19**	**L20**	**L21**	**L22**	**L23**
Avg	-0.03	-0.03	-0.09	-0.10	-0.07	0.00	-0.10	-0.17	-0.12	-0.03	-0.17	-0.01	-0.06	0.08	-0.05	-0.02	-0.19	-0.04	0.13		0.08	-0.16	-0.01
Max	0.07	0.06	0.02	-0.03	0.11	0.10	-0.06	-0.03	0.05	0.11	-0.07	0.24	0.06	0.20	0.07	0.23	-0.11	0.05	0.34		0.23	0.06	0.16
Min	-0.13	-0.16	-0.23	-0.22	-0.27	-0.13	-0.18	-0.32	-0.23	-0.20	-0.34	-0.18	-0.14	0.03	-0.21	-0.23	-0.28	-0.24	0.02		-0.06	-0.31	-0.21

5. 3 Results: Tilt-meters and crack-meters

Tilt-meters were placed at locations selected by an MSA appointed committee. The locations were considered unusually sensitive to unexpected foundation movement. The movement tolerance was assessed to be less than 0.5 mm of movement.

The collected data indicated no excessive tilting of any monuments under observation during the latest reporting period. Table 9 presents the location and length of the tilt beams and table 10 summarizes the data collected from Crack-meters and Tilt-beams.

Table 9. Tilt-beam location and length

Point ID	Location	Length	Position
B1	KARNAK TEMPLE (Hypostyle hall)	1 meter	Horizontal
B2	KARNAK TEMPLE (Tenth pylon)	2 meters	Horizontal
B3	LUXOR TEMPLE (Court of AmenhotepIII)	1 meter	Horizontal
B4	LUXOR TEMPLE (AmenhotepIII hypostyle hall)	1 meter	Horizontal
B5	LUXOR TEMPLE (Pylon of RamsesII)	2 meters	Vertical

Table 10 Average, max and minimum Crack-meter and Tilt-beam measurements

	KARNAK TEMPLE – (mm)				LUXOR TEMPLE - (mm)				
Points	**C1**	**C2**	**B 1**	**B 2**	**C3**	**C4**	**B 3**	**B 4**	**B 5**
AVG	-0.22	0.12	-0.03	-0.02	0.04	0.29	0.08	-0.03	0.06
MAX	-0.12	0.31	0.02	0.03	0.20	0.36	0.09	-0.01	0.17
MIN	-0.40	0.02	-0.08	-0.04	-0.21	0.22	0.06	-0.05	-0.04

C *refers to the Crack-meter points*
B *refers to the Tilt-beam points*

The following tables show the summary of the monitoring data collected during the period of the report sorted according to the location inside the Karnak and Luxor temples.

Table 11 Summary of survey measurements at Luxor temple

Object Name	Monitoring points	Kind of Monitoring Point	Changes from the first measurement (mm)			Tolerance Limit (mm)
			Average	Max.	Min.	
Obelisk of Ramses II	L1	Precise level	-0.03	0.07	-0.13	±3.0
	P1 ΔE	Total station	0.03	0.32	-0.17	±3.0
	ΔN		0.03	0.17	-0.21	±3.0
	P2 ΔE	Total station	-0.46	-0.05	-0.68	±3.0
	ΔN		-0.39	-0.08	-0.60	±3.0
Pylon of Ramses II	L2	Precise level	-0.03	0.06	-0.16	±3.0
	P3 ΔE	Total station	-0.07	0.50	-0.46	±3.0
	ΔN		-0.09	0.06	-0.23	±3.0
	P4 ΔE	Total station	0.60	0.95	0.18	±3.0
	ΔN		-0.96	-0.63	-1.15	±3.0
	B5	**Tilt beam**	0.06	0.17	-0.04	±0.5
Abu Al-Haggag Mosque	L3	Precise level	-0.09	0.02	-0.23	±3.0
	L4	Precise level	-0.10	-0.03	-0.22	±3.0
	C3	**Crackmeter**	0.04	0.20	-0.21	±0.5
Court of Ramses II	L5	Precise level	-0.07	0.11	-0.27	±3.0
	L6	Precise level	0.00	0.10	-0.13	±3.0
	L7	Precise level	-0.10	-0.06	-0.18	±3.0
	L8	Precise level	-0.17	-0.03	-0.32	±3.0
	B4	**Tilt beam**	-0.03	-0.01	-0.05	±0.5
	P5 ΔE	Total station	-0.01	0.12	-0.11	±3.0
	ΔN		0.15	0.25	0.03	±3.0
Colonnade of Amenhotep III	P6 ΔE	Total station	0.79	1.01	0.54	±3.0
	ΔN		-0.85	-0.70	-1.01	±3.0
	L9	Precise level	-0.08	0.13	-0.23	±3.0
	L10	Precise level	-0.03	0.11	-0.20	±3.0
	L11	Precise level	-0.17	-0.07	-0.34	±3.0
	L12	Precise level	-0.01	0.24	-0.18	±3.0
	L13	Precise level	-0.06	0.06	-0.14	±3.0
	L14	Precise level	0.08	0.20	0.03	±3.0

Object Name	Monitoring points	Kind of Monitoring Point	Changes from the first measurement (mm)			Tolerance Limit (mm)
			Average	Max.	Min.	
Court of Amenhotep III.	L15	Precise level	-0.05	0.07	-0.21	±3.0
	L16	Precise level	-0.02	0.23	-0.23	±3.0
	L17	Precise level	-0.19	-0.11	-0.28	±3.0
	B3	**Tilt beam**	0.08	0.09	0.06	±0.5
Amenhotep III Hypostyle Hall	L18	Precise level	-0.04	0.05	-0.24	±3.0
	L19	Precise level	0.13	0.34	0.02	±3.0
	C4	**Crack-meter**	0.29	0.36	0.22	±0.5
Twelve Column hall.	L20	Precise level				±3.0
	L21	Precise level	0.08	0.23	-0.06	±3.0
Sanctuary of Amun-Ra	L22	Precise level	-0.16	0.06	-0.31	±3.0
	L23	Precise level	-0.01	0.16	-0.21	±3.0
	P7 ΔE	Total station	0.57	0.68	0.46	±3.0
Court of Amenhotep III.	ΔN		0.70	0.84	0.53	±3.0
	P8 ΔE	Total station	0.84	1.12	0.45	±3.0
	ΔN		0.62	0.67	0.48	±3.0

Table 12 Summary of survey measurements at Karnak temple

Object Name	Monitoring points	Kind of Monitoring Point	Change from the first measurement (mm)			Tolerance Limit (mm)
			Average	Max.	Min.	
Second pylon	K1	Precise Level	0.0	0.3	-0.2	±3.0
	K2	Precise Level	0.0	0.1	-0.3	±3.0
	C2	**Crack meter**	0.1	0.3	0.0	±0.5
Hypostyle Hall (the North Side)	K3	Precise Level	0.0	0.1	-0.1	±3.0
	K4	Precise Level	0.2	0.3	0.0	±3.0
	K5	Precise Level	-0.1	0.1	-0.2	±3.0
	K6	Precise Level	0.1	0.2	0.0	±3.0
	B1	**Tilt Beam**	0.0	0.0	-0.1	±0.5
Obelisk of Tuthmosis I.	K7	Precise Level	0.1	0.1	0.0	±3.0
	S1 ΔE	**Total Station**	0.4	0.8	0.2	±3.0
	ΔN		0.4	0.7	0.1	±3.0
	S2 ΔE	**Total Station**	-0.4	-0.1	0.2	±3.0
	ΔN		0.8	1.0	0.6	±3.0

Object Name	Monitoring points	Kind of Monitoring Point	Change from the first measurement (mm)			Tolerance Limit (mm)
			Average	Max.	Min.	
Ninth Pylon	K8	Precise Level	-0.1	0.1	-0.2	±3.0
	K9	Precise Level	-0.1	0.0	-0.2	±3.0
	K10	Precise Level	-0.1	0.1	-0.2	±3.0
	K11	Precise Level	-0.1	0.1	-0.3	±3.0
	S3 ΔE	**Total Station**	-0.5	-0.1	-0.9	±3.0
	ΔN		-0.2	0.1	-0.5	±3.0
	S4 ΔE	**Total Station**	0.3	0.5	-0.1	±3.0
	ΔN		-0.1	0.3	-0.3	±3.0
	S5 ΔE	**Total Station**	-0.2	0.3	-0.5	±3.0
	ΔN		-0.2	0.5	-1.2	±3.0
	S6 ΔE	**Total Station**	-0.3	0.1	-0.4	±3.0
	ΔN		-0.2	-0.1	-0.4	±3.0
	S7 ΔE	**Total Station**	0.4	0.8	-0.4	±3.0
	ΔN		0.3	0.8	-0.4	±3.0
	S8 ΔE	**Total Station**	-0.2	0.4	-0.5	±3.0
	ΔN		0.1	0.7	-0.5	±3.0
Tenth Pylon	K12	Precise Level	-0.1	0.0	-0.2	±3.0
	K13	Precise Level	-0.1	0.0	-0.2	±3.0
	S9 ΔE	**Total Station**	0.2	0.3	0.0	±3.0
	ΔN		0.2	0.5	-0.1	±3.0
	S10 ΔE	**Total Station**	0.0	0.6	-1.1	±3.0
	ΔN		-0.3	-0.2	-0.6	±3.0
	S11 ΔE	**Total Station**	-0.2	0.1	-0.8	±3.0
	ΔN		0.5	0.8	0.0	±3.0
	S12 ΔE	**Total Station**	-0.7	-0.3	-1.1	±3.0
	ΔN		-0.1	0.1	-0.6	±3.0
	B2	**Tilt Beam**	0.0	0.0	0.0	±0.5

Object Name	Monitoring points	Type of Monitoring Point	Change from the first measurement (mm)			Tolerance Limit (mm)
			Average	Max.	Min.	
Khonsu Gate	K14	Precise Level	-0.2	-0.1	-0.3	±3.0
	K15	Precise Level	-0.1	-0.1	-0.2	±3.0
	S13 ΔE	**Total Station**	0.0	0.3	-0.4	±3.0
	ΔN		0.2	0.9	-0.5	±3.0
	S14 ΔE	**Total Station**	-0.5	-0.1	-0.7	±3.0
	ΔN		-0.6	-0.2	-0.9	±3.0
	S15 ΔE	**Total Station**	-0.1	0.9	-0.7	±3.0
	ΔN		0.3	1.0	-0.3	±3.0
	S16 ΔE	**Total Station**	0.2	0.4	-0.2	±3.0
	ΔN		-0.3	0.0	-0.6	±3.0
	C1	**Crack -meter**	-0.2	-0.1	-0.4	±0.5
Eastern Gate	K16	Precise Level	0.1	0.3	0.0	±3.0
	K17	Precise Level	-0.2	-0.1	-0.3	±3.0
	K18	Precise Level	-0.2	-0.1	-0.3	±3.0
	K19	Precise Level	-0.1	0.1	-0.2	±3.0
	S21 ΔE	**Total Station**	0.1	0.8	-0.4	±3.0
	ΔN		-0.5	-0.3	-0.8	±3.0
	S22 ΔE	**Total Station**	0.0	0.5	-0.5	±3.0
	ΔN		-0.4	0.1	-0.7	±3.0
	S23 ΔE	**Total Station**	0.2	1.0	-0.6	±3.0
	ΔN		-0.3	-0.2	-0.5	±3.0
	S24 ΔE	**Total Station**	0.1	0.8	-0.4	±3.0
	ΔN		-0.1	0.1	-0.2	±3.0
	S25 ΔE	**Total Station**	-0.3	0.1	-0.8	±3.0
	ΔN		0.5	0.7	0.3	±3.0
	S26 ΔE	**Total Station**	0.1	0.7	-0.4	±3.0
	ΔN		-0.5	-0.2	-1.0	±3.0

Object Name	Monitoring points	Type of Monitoring Point	Change from the first measurement (mm)			Tolerance Limit (mm)
			Average	Max.	Min.	
Montu Gate	K20	Precise Level				±3.0
	K21	Precise Level	-0.2	-0.1	-0.2	±3.0
	K22	Precise Level	0.0	0.2	-0.2	±3.0
	K23	Precise Level	-0.1	-0.1	-0.2	±3.0
	S17 ΔE	**Total Station**	-0.4	-0.3	-0.6	±3.0
	ΔN		-0.3	-0.2	-0.4	±3.0
	S18 ΔE	**Total Station**	-0.3	0.2	-1.0	±3.0
	ΔN		0.0	0.5	-0.4	±3.0
	S19 ΔE	**Total Station**	-0.2	0.0	-0.5	±3.0
	ΔN		0.0	0.3	-0.5	±3.0
	S20 ΔE	**Total Station**	-0.3	0.0	-0.6	±3.0
	ΔN		-0.3	0.0	-0.6	±3.0

6 Summary

From the differences between the initial readings and the observed readings, one can conclude the following:

a. The differences in level points in Karnak temple have mean value -0.01 mm and standard deviation 0.04mm. On the other hand, the differences in level points in Luxor temple have mean value -0.05mm and 0.03mm standard deviation. These values are within the accuracy of the used precise level instrument.

b. The differences in total station points in Karnak temple have mean value 0.12mm, and standard deviation 0.26mm. On the other side, the differences in total station points in Luxor temple have mean value 0.02 mm and standard deviation 0.27mm. These values are within the accuracy of the used total station instrument.

c. The above findings agree with the main program of monitoring as contracted to SMT by the MSA which is conducted daily for different locations in both temples.

7 Conclusions

The groundwater observations confirm that average groundwater levels at both temples have been successfully lowered to the target level as a result of the groundwater lowering project. The target-level of the project is <72.0 m.a.s.l. for Karnak temple area and <71.5 m.a.s.l. for Luxor temple area.

Measurements of temple movement suggest that no significant settlement of temple structures has occurred during the report period. Special locations considered to be particularly sensitive to movement - where the tilt-meters and crack-meters are installed - have remained stable up to the end of the reporting period.

8 Recommendations

The following is a remaining recommendation for performance improvement in the months ahead.

- Calibrate the groundwater discharge flow meters in both Karnak and Luxor temples pump stations.