APPENDIX F

ENVIRONMENTAL AND SOCIAL CONSIDERATION

F-1. Groundwater Monitoring Report

ARAB REPUBLIC OF EGYPT
MINISTRY OF WATER RESOURCES AND IRRIGATION
RESERVOIR AND GRAND BARRAGES SECTOR

DETAILED DESIGN STUDY
ON
THE PROJECT FOR CONSTRUCTION OF
THE NEW DIROUT GROUP OF REGULATORS
IN
THE ARAB REPUBLIC OF EGYPT

Groundwater Monitoring Report

April, 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

SANYU CONSULTANTS INC.

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1. General Description and Purpose of the Survey

1.1 General description of the survey

The survey for the "Groundwater Monitoring of Boring Holes and Existing Wells - Detailed design on the Project for Construction of the New Dirout group of Regulators" was implemented to collect the time seires data of the change in groundwater level and its quality.
The Dirout Group of Regulators (hereinafter referred to as DGRs) which contains 5 regulators and 7 cananls and provides water for an area of about 1.6 million feddan. DGRs is located 60.6 km downstream intake of Ibrahimia canal, by distance 60 km from Assiut and about 380 km south of Cairo as shown in Figure 1.1.

The contractor of the survey was Environment and Climate change Research Institute (hereinafter referred to as ECRI) since January 2016. All the monitoring and inventory work has been done with the staff from Sanyu Consultants Inc. and Reservoirs and Grand Barrages Sector (hereinafter referred to as RGBS), ended 6th April 2017. The survey synopsis is shown in Table1.1.

Table 1.1 Survey synopsis

Survey Title	Groundwater Monitoring of Boring Holes and Existing Wells - Detailed design on the Project for Construction of the New Dirout group of Regulators
Contractor	Environment and Climete changes Research Institute (ECRI)
Project Area	Dirout city, Assiut Pref. Egypt - Area of 1,300m x 1,300m from the center of DGRs
Work Item	Well Inventory Survey for the existing wells Groundwater Level Monitoring Survey Water Quality Survey
Project Start Date	October 2015 (at the completion of each monitoring well)
Project Duration	1 year and 7 months – ending in April 2017

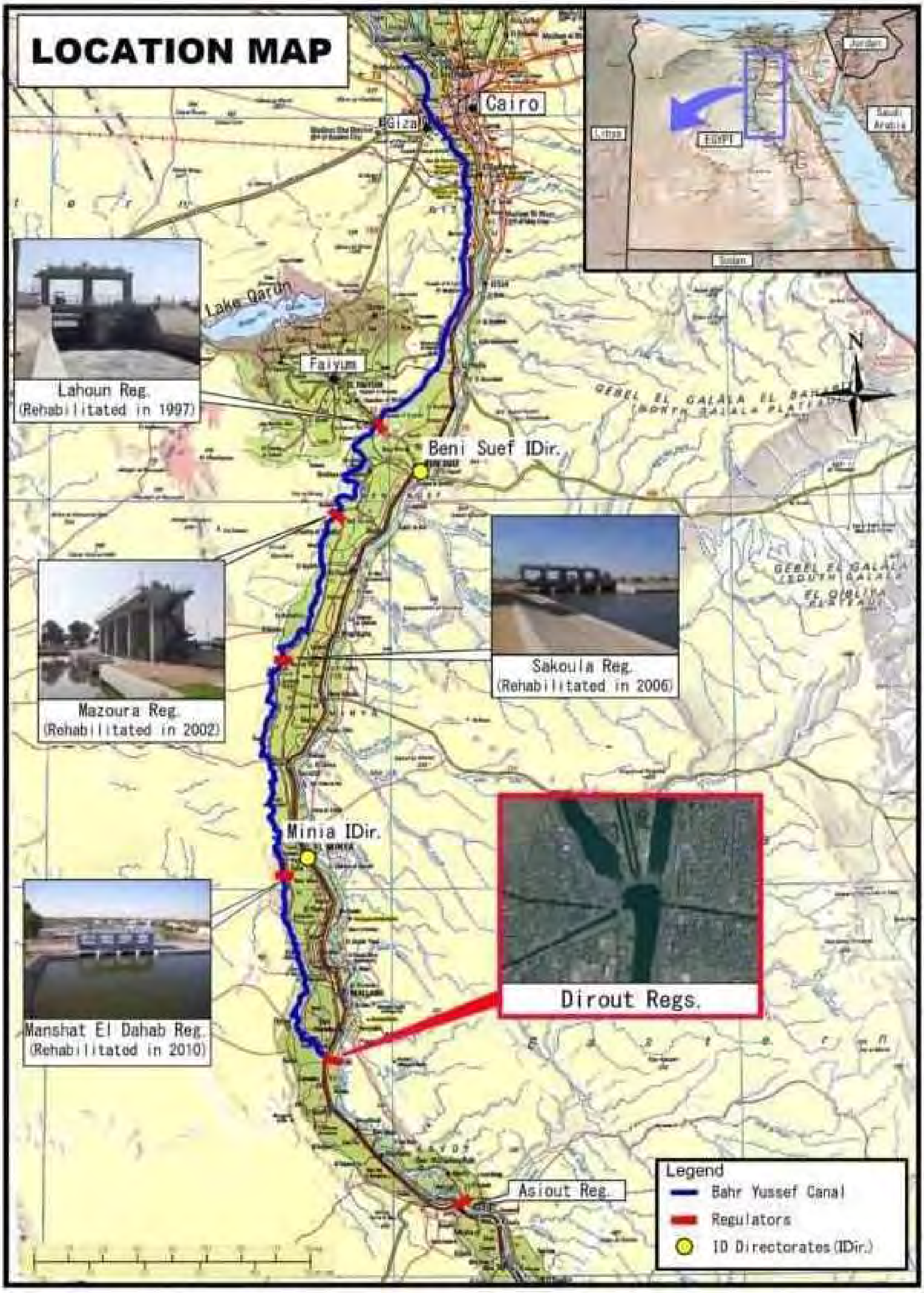


Figure 1.1 Location of DGRs

1.2 Purpose of the survey

As a result of the construction of NDGRs which axis will be located at the distance of 140m downstream from DGRs, water level in the 140m section is expected to rise compared to the current condition. It was already reported that residents were suffered from the wet ground in their houses. Considering the Dirout city becomes urbanized these days, the rise in canal water level may bring more adverse impact to larger number of residents. In this context, the extent of groundwater rise and its countermeasures should be studied before the construction begins. Therefore, monitoring survey plays a significant role to the followings;

1) To grasp the hydraulic mechanism of the aquifer
2) To record the time series data for groundwater modelling for the prediction of the future groundwater rise and evaluation of the countermeasures

In addition, Environmental Impact Assessment (EIA) which is authorized by MWRI recommends the continuous groundwater monitoring (both water level and quality) before/during/after construction of NDGRs. Besides, groundwater is still sometimes utilized as drinking water when the water supply system is cut off. Therefore, the followings are also the purpose of the monitoring;

3) To record the baseline quality to compare the change in water quality during/after the construction.
4) To compare the water quality with the Egyptian guideline for drinking water

1.3 General hydrogeological features in the study area

Geological structures around Dirout city feature an erosion valley striding over 15km to 20km beyond the river terrace developed over different geological times. Diluvium formation which formed the river terrace is consequently seen under the river Nile, but alluvium sediments are covered in the study area which is beside the current river Nile. The condition of the Nile deposits depends on changes in hydraulic gradient caused by eustasy, and changes in the river course caused by tectonism (shown on Figure 1.2). The geological field survey of the study area corresponds to the Neonile or Prenile description (Said 1993). Table 1.2 shows the features for those units.

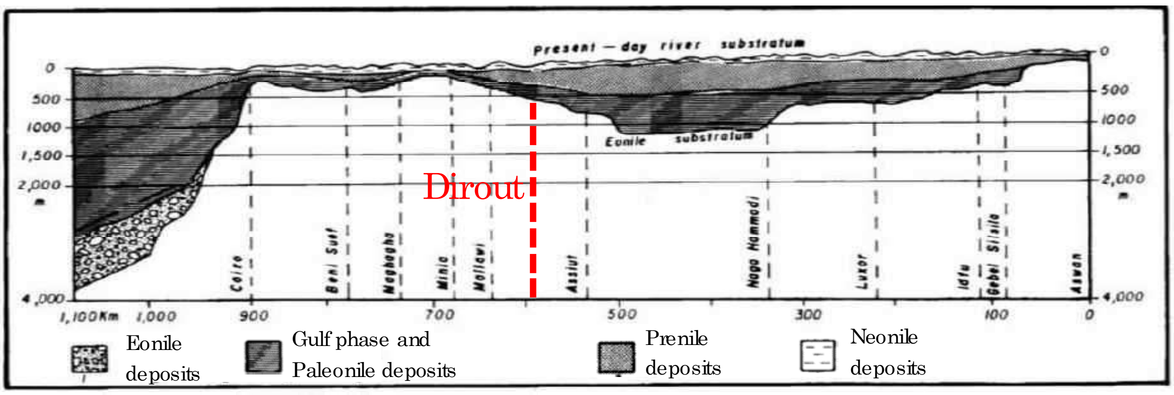


Figure 1.2 Geological profile of the Nile (Aswan to Mediterranean sea)
(Source: Rushdi Said The River Nile, 1993)

Table 1.2 Description of flood sediments

Unit	Remarks (Stratigraphication and distribution)
Neonile	This river system is the current condition of the Nile (0.4Ma-present), and is categorized into 4 types of deposits, α, β, γ, and δ-Neonile considering the regression/transgression cycle. They are mainly composed of riverine (flood) deposits (silt and sand, and occasional gravel) and inter-fingered dune sand.
Prenile	It is mainly composed of two types of sand layers, one for cross-bedding riverine sand, and another for inter-bedding dune sand in the middle Pleistocene (0.8 – 0.4Ma). The deposit from this river system includes mollusca and fauna which indicate that this river system is connected to Ethiopia (Said 1990). This river system conveyed massive amounts of sand on the Nile valley which resulted in considerably thick sand layer even in Upper Egypt.

The solil structure in the study area is composed of the Nile deposit which has been aggraded since the late Pleistocene. According to the result of the past geological suvey, the Nile silt layer (approximately 10m depth from the surface) is covering the sand layer which has the gradation sequence in the diameter of sand (from fine sand to coarse sand with interbedded gravel) in response to regression.

The target aquifer for the monitoring is the sand layer (especially at the depth of 20m to 25m where unconsolidated coarse sand dominants). Although the aquifer is confined for most areas due to impermeable silt layer on the surface, te sand layer is exposed on the bottom of canals in some area, which seems to indicate that the target aquifer can have a direct connection with canals to a certain extent (refer to ① in Figure 1.3). Therefore, the type of the aquifer in the study area can be evaluated as a confined aquifer recharged by canal water.

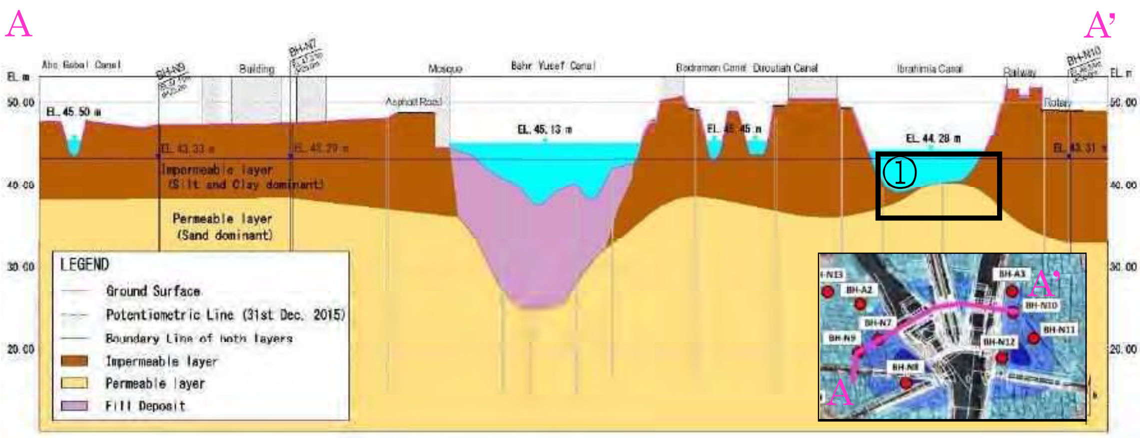


Figure 1.3 Cross section map on the new axis line

(*①: unconfined area which directly connects to sand layer)
)

2 Contents and Methodology of the Survey

2.1 Well inventory survey

The survey was carried out in accordance with following 3 steps.

a) Collecting existing records

Any useful information for the existing wells in the vicinity of NDGRs such as registration records, well ledgers, academic reports etc. were collected to grasp the location of existing wells.

b) Field survey

In order to obtain factual information, the survey was conducted with questionnaire sheets comprising the location (coordination), well specifications (depth, bore, screen depth), and usage condition (daily pumping withdrawn amount, frequency of useage), etc.

Table 2.1 Survey items for inventory survey

Item	Contents
a) Location	Latitude and Longitude
b) Specification	Pumping method, well depth, screen depth, the date installed
c) Pumping amount	Pumping amount and its frequency
d) Others	Groundwater level, purpose for pumping and years after utilization

c) Data input

Data collected by the step 1 and 2 was organized in the sheet.

2.2 Groundwater moniroting of monitoring wells

Groundwater monitoring at thirteen monitoring wells installed by the other survey “Groundwater monitoring for Groundwater Monitoring” was carried out two or three times per month. The monitoring continued until the end of April 2017. The survey team also checked the condition of the monitoring wells when they made the motniring at site, and appropriate maintenance was taken if they have any problem in the monitoring.

For measuring the water quality (EC, pH and DO), groundwater was taken after measuring the groundwater level. Bailer watere sampling device is used to collect the water specimen at the depth of 20m.

Table 2.2 Monitoring item and frequency

Monitoring Item	Frequency	Remarks
Groundwater Level	2 - 3 times/ month	until April 2017
Groundwater Quality (EC. pH, DO)	2 - 3 times/ month	until April 2017 sampled at the depth of 20m
Groundwater Quality (the other items)	4 times (2 points×2 times)	implemented in July 2016 and January 2017

2.2.1 Location and specification of the monitoring wells

Thirteen monitoring wells were installed in the area shown in Figure 2.1 and Table 2.3. Length of the monitoring well is basically 30m which has enough depth to reach the aquifer. In order to prevent from inflow of surface water, monitoring wells were installed surrounded with concrete block until 0.5m, bentonite powder from 0.5m to 3.0m, bentonite pellet from 3.0m to 11.0m, and sand from 11.0m to 12.0m in depth. Gravel filter was filled from depth of 12.0m to the bottom of boreholes to evaluate aquifer. Strainer (φ50mm, longitudinal slit, aperture ratio: approx. 3%) was installed at 1.0m to 4.0m from the bottom of borehole. As the protection work, steal protection casing with a cover top (length: 3m, φ100mm) was also installed. Figure 2.2 shows the typical comparison between the general structure of monitoring well and geological classification.

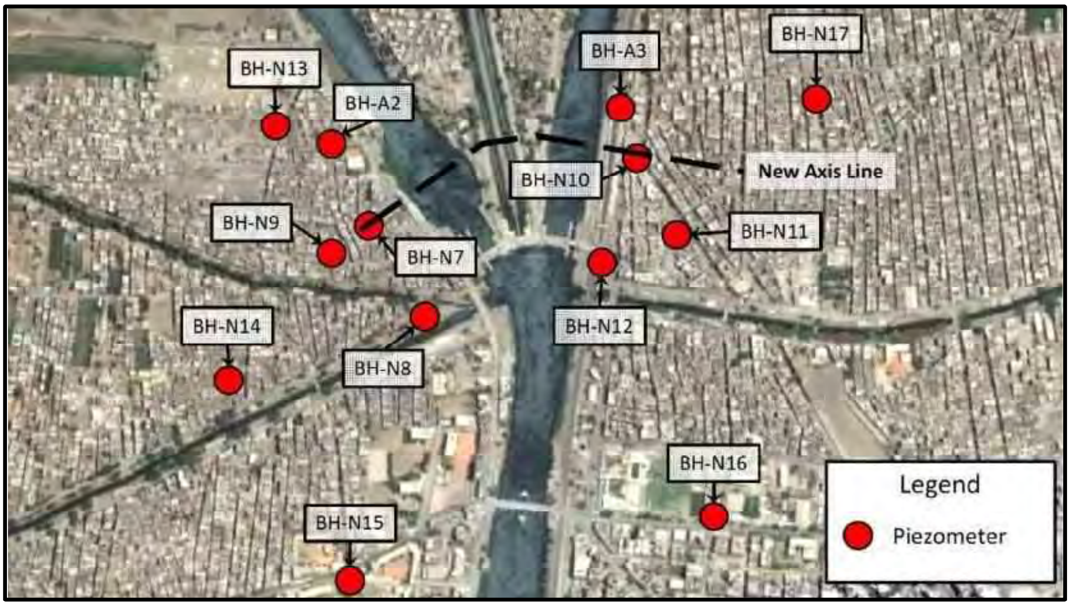


Figure 2.1 Location map of monitoring wells

Table 2.3 Coordinates of monitoring wells and hand pump wells

Hole	Coordinates				Elevation (EL.m)	Remark
	X (UTM36, m)	Y (UTM36, m)	Easting (WGS84,DD)	Northing (WGS84,DD)		
BH-N7	283664.8	3050278.6	30.8089	27.5591	47.308	
BH-N8	283741.5	3050126.8	30.8097	27.5578	47.509	
BH-N9	283626.6	3050225.5	30.8085	27.5586	47.110	
BH-N10	284076.7	3050375.4	30.8131	27.5600	48.835	
BH-N11	284150.1	3050292.9	30.8138	27.5593	47.615	
BH-N12	284043.5	3050222.9	30.8127	27.5587	50.913	
BH-A2	283606.6	3050413.2	30.8083	27.5603	46.997	
BH-A3	284074.3	3050454.8	30.8130	27.5608	49.593	
BH-N13	283523.3	3050452.7	30.8074	27.5607	45.885	
BH-N14	283437.3	3050038.3	30.8066	27.5569	46.841	
BH-N15	283623.7	3049686.9	30.8086	27.5538	46.769	
BH-N16	284212.5	3049791.0	30.8145	27.5548	46.530	
BH-N17	284383.6	3050462.6	30.8161	27.5609	46.670	

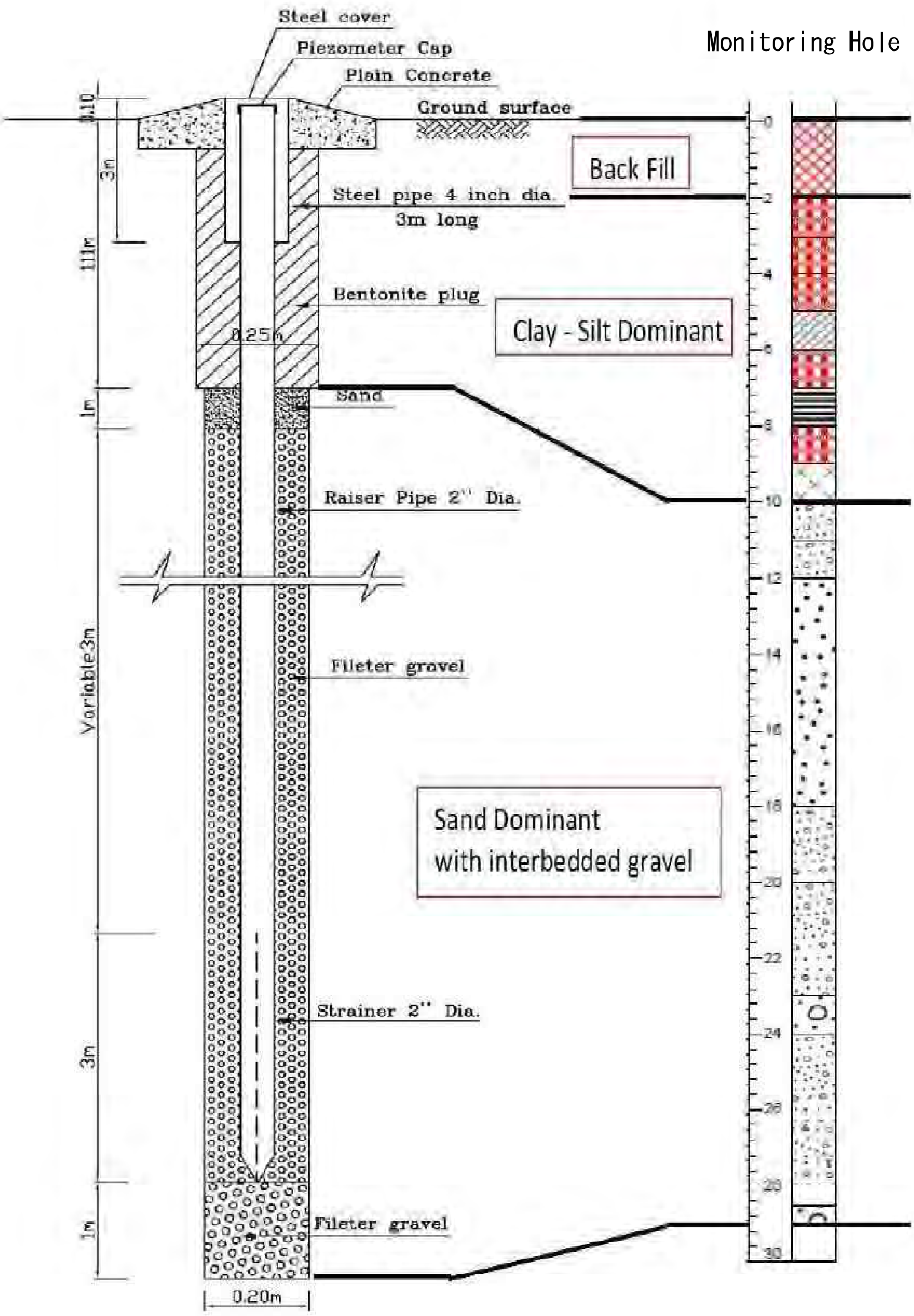


Figure 2.2 Comparison between the structure of monitoring well and typical geological classification

2.3 Simultaneous monitoring survey

The groundwater monitoring was also simultaneously carried out for thirteen monitoring wells and maximum twenty existing wells depending on the result of well inventory survey in the same day. It was implemented twice a year (July 2016 and January 2017) for four items (groundwater level, Electric Conductivity (EC), Dissolved Oxygen (DO), and Potential Hydrogen (pH)). Contour maps for monitoring wellic surface, EC, DO, pH were made after the monitoring survey.

Table 2.4 Work schedule of groundwater monitoring

Work Item	Qty.	2015			2016					
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar	Apr	May	Jun
Groundwater Monitoring (GWL)	2 - 3 times/ month 13 samples	▲ ▲	▲ ▲	▲ ▲	▲ ▲	▲▲▲	▲ ▲	▲ ▲	▲ ▲	▲▲▲
Simultaneous Survey	2times × 13 (+existing wells if any) samples									
Water Quality Test	2times × 2 samples									

Work Item	Qty.	2016						2017			
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Groundwater Monitoring (GWL)	2 - 3 times/ month 13 samples	▲▲▲	▲▲▲	▲ ▲	▲ ▲	▲ ▲	▲ ▲	▲▲▲▲	▲▲	▲▲▲	▲
Simultaneous Survey	2times × 13 (+existing wells if any) samples	▲						▲			
Water Quality Test	2times × 2 samples	▲						▲			

2.4 Detailed water quality test

During the simultaneous monitoring survey, two sampling points (BH-N7 and BH-N10 which are on the new axis lines) were arbitrary selected for the water quality test which examines the following twenty-seven items. It was implemented twice (in July 2016 as a high water-demand season and January 2017 as a low water-demand season).

Table 2.5 Test Items for water quality test

・Physical and Chemical Property	・Hydro-chemical Property	・Trace Element and Heavy Minerals
1 Temperature	11 Calcium (Ca)	17 Nitrate (NO3)
2 pH	12 Magnesium (Mg)	18 Nitrite (NO2)
3 Electric Conductivity	13 Sodium (Na)	19 Phosphate (SO4)
4 Turbidity	14 Pottasium (K)	20 Sulfate (S)
5 Total Dissolved Solid	15 Chloride (Cl)	21 Chromium (Cr)
6 Total Suspended Solid	16 Sulfate (SO4)	22 Copper (Cu)
7 Chemical Oxygen Demand		23 Iron (Fe)
8 Biochemical Oxygen Demand		24 Manganese (Mn)
9 CO3, HCO3		25 Nickel (Ni)
10 Total Alkalinity		26 Lead (Pb)
		27 Zink (Zn)

Equipment and instruments used for the survey were as follows;

Table 2.6 Field equipment for the monitoring

Item	Equipment Brand and Specification	Pictures
1	Solint Water level Meter Range: Length: 50 m Resolution:0.1 cm	
2	ECRI Groundwater Sampler (non-return valve) Volume : 1.0 litre	
3	YSI EcoSense DO200A Dissolved Oxygen Meter Range: DO % air saturation: -0 to 200% DO: ppm (mg/L)- to 20 mg/L Temperature: 0 to 50° C (32 to 122 °F)	
4	YSI EcoSense EC300A Conductivity Meter Range: Conductivity :-0 to 499.9 μS/cm, 0 to 4999 μS/cm, 0 to 49.99 mS/cm, 0 to 200.0 mS/cm Salinity: -0.0 to 70.0 ppt, TDS: 0.30 to 1.00 g/L, Temperature: -10 to +90°C (14 to 194°F)	
5	YSI EcoSense pH100A Meter Range: pH range: -2 to 16 units mV: -1999 to +1999 mV Temperature: -10 to +120°C (14 to 248°F)	

Item	Equipment Brand and Specification	Pictures
6	pH meter – Sartorius-ph10 Measuring Range pH: -2 to +14 Temperature: -5 to +105 °C	
7	Lovebond -Turbidirct Range: Turbidity: 0.01 – 1100 NTU (Auto range) Resolution: 0.01 from 0.01 - 9.99 (NTU) 0.1 NTU from 10.0 - 99.9 1 NTU from 100 - 1100 Accuracy: ⊥ 2 % of reading or 0.01 (NTU) (0 - 500) ± 5 % of reading (500 - 1100) Ambient :temperature: 5-40°C at 30-90% Conditions relative humidity(non condensing	
8	EurekaWater Quality Multiprobe Manta2 1-PH Range: 0~14 Resolution: 0.01 2- dissolved oxygen Range: 0:25 mg/l Resolution:0.1mg/l 3-coundictivity Range: 0:100ms/cm Resolution:4digits 4-temperature Range: -5:50°C Resolution: 0.01°C *only specs for the used function	

Item	Equipment Brand and Specification	Pictures
9	ICP-OES Perkin Elmer Optima 5300 DV	
10	Ion Chromatography Dionex DX-500	

3 Result and Discussion

3.1 Well inventory survey

Survey team went to the site for the well inventory survey to clarify the location of the wells twice (22nd March and 4th April 2016). Before the survey, the survey team found one academic paper indicating there are two wells which depth is more than 50m in Dirout city (Ahmed, Mahmoud and Rasha 2013). However, it turned out the coordination of the well in the paper was wrong, and therefore, it is not considered in the survey. Thorough the inventory survey which contains interviews to 105 residents on 15th and 22nd March 2016, the study team collected the information below.

a) Location of the wells

Thirty-two hand pump wells were found but no wells at which the water level can be monitored. Among them, nine hand pump wells (one of them is broken) are located inside of the study area shown in Figure 3.1, and the location of all the hand pump wells are shown in Figure 3.2 and Table 3.1. Most hand pump wells are located along the Abo Gabal and Irad Delgaw canal, and no well was found on the east side of the Irahimia canal.

b) Structure of the wells

According to the hearing result from the residents, those hand pump wells have 1.5 inch in diameter, and was constructed between 6 and 10 years ago. Depth of the well is 10m to 20m from the ground surface, therefore, it seems to withdraw that from the sand layer. It is unrealistic to measure the groundwater level considering its structure, only the water quality (EC, pH, DO) was measured during the simulataneous survey.

c) Purpose of the groundwater usage

The hand pump wells found in the study area are utilized for the domestic chores, livestock, and also for drinking pupose in case the water supply system cuts off. It happens mainly in the area between Irad Delgaw canal and Bahr Yusef canal because it is newly developed resident area. Considering the conditions that people consume 50L/day/person of water and each pump serves 10 households (estimating 70 people), withdrawn discharge volume is estimated as $0.05m^3$/day/pump× 70people = $3.5m^3$/day/pump.

d) The other remarks

All the interviewees mainly use the portable drinking water system from tap water to get fresh water but it has a lot of turbidity and therefore they feel it is not suitable for drinking purpose (31 persons out of the 107 mentioned that, they need the project to construct a deep groundwater well outside the residential area).

As for the sewage treatment method, all the people agreed that there is a sewage network in the study area, but it is not working. Therefore, they use two types of sewage system: underground tank system to store their wastewater and deep borehole system to drain the sewage off into underground, which pollutes the groundwater. All the random sample agreed that, a vehicle used to visit the area to suck the wastewater from the underground tank, after that, they dump it in the canal, which pollutes the surface water. Therefore, kidney and laver are the dominated diseases in the study area.

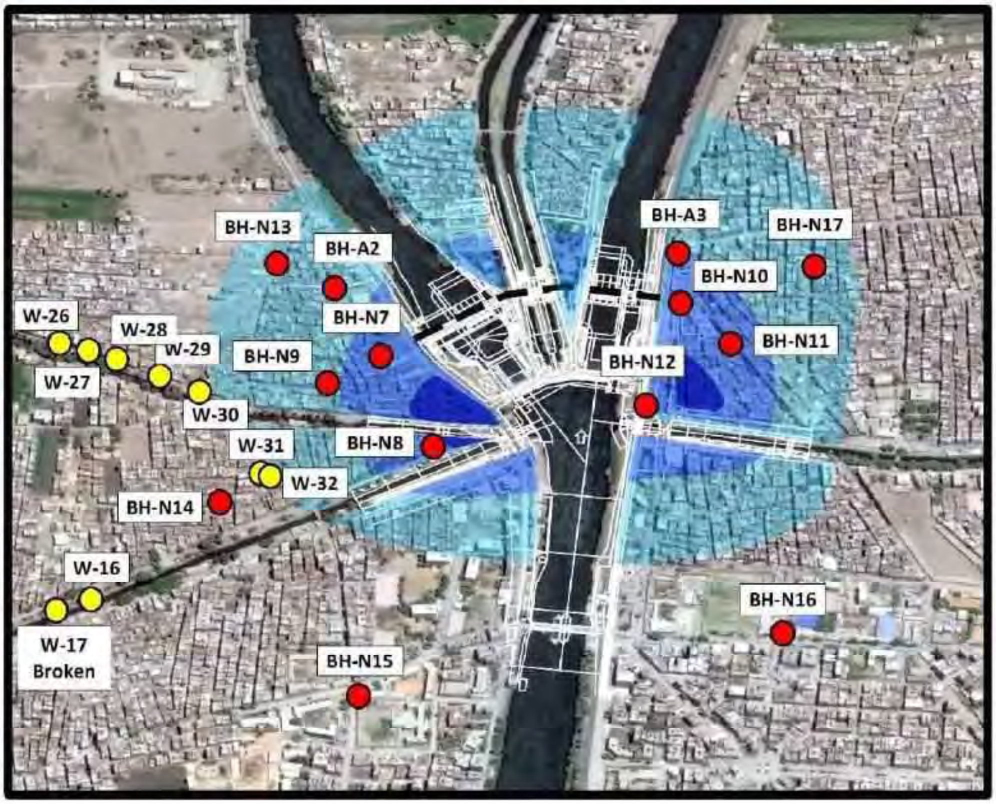


Figure 3.1 Location of the existing wells and monitoring wells after inventory survey

Figure 3.2 Location of the existing well and monitoring wells after inventory survey (including the hand pump wells outside of the study area)

Table 3.1 Coordinates of monitoring wells and hand pump wells

Name	Coordinates				Remark
	X (UTM36, m)	Y (UTM36, m)	Easting (WGS84,DD)	Northing (WGS84,DD)	
WP-1	283055.9	3049763.0	30.8028	27.5544	Broken Out of study area
WP-2	282680.4	3049592.3	30.7991	27.5528	Broken Out of study area
WP-3	282510.4	3049535.4	30.7974	27.5522	Out of study area
WP-4	282288.8	3049518.3	30.7951	27.552	Out of study area
WP-5	282554.7	3049581.2	30.7978	27.5526	Out of study area
WP-6	282612.3	3049595.7	30.7984	27.5528	Out of study area
WP-7	282634.2	3049607.5	30.7986	27.5529	Out of study area
WP-8	282702.8	3049632.9	30.7993	27.5531	Out of study area
WP-9	282761.5	3049657.4	30.7999	27.5534	Out of study area
WP-10	282789.7	3049683.5	30.8002	27.5536	Broken Out of study area
WP-11	282840.2	3049693.6	30.8007	27.5537	Out of study area
WP-12	282867.2	3049707.6	30.8009	27.5538	Out of study area
WP-13	282992.8	3049769.6	30.8022	27.5544	Out of study area
WP-14	283047.6	3049797.5	30.8027	27.5547	Broken Out of study area
WP-15	283106.2	3049817.5	30.8033	27.5549	Out of study area
WP-16	283145.1	3049837.9	30.8037	27.5551	Out of study area
WP-17	283199.9	3049862.4	30.8043	27.5553	Broken
WP-18	283232.8	3049877.3	30.8046	27.5554	
WP-19	282964.6	3050408.6	30.8018	27.5602	Broken Out of study area
WP-20	282792.9	3050643.4	30.8000	27.5623	Out of study area
WP-21	282792.6	3050679.9	30.8000	27.5626	Broken Out of study area
WP-22	282847.5	3050548.2	30.8006	27.5614	Broken Out of study area
WP-23	282949.3	3050435.5	30.8016	27.5604	Broken Out of study area
WP-24	283032.4	3050389.7	30.8025	27.5600	Out of study area
WP-25	283143.3	3050346.7	30.8036	27.5596	Out of study area
WP-26	283241.4	3050306.2	30.5046	27.5593	
WP-27	283264.7	3050286.9	30.8049	27.5591	
WP-28	283317.8	3050273.8	30.8054	27.559	
WP-29	283374.0	3050253.0	30.806	27.5588	
WP-30	283412.9	3050231.1	30.8064	27.5586	
WP-31	283488.0	3050061.0	30.8072	27.5571	
WP-32	283494.0	3050056.0	30.8072	57.557	

Table 3.2 Summary sheet for the result of the Inventory Survey

1-	Are there any water pump?					
	Yes ■ 23		No ■ 82			
2-	Pump Type					
	Manual ■ 23	Electronic □		Other □		
3-	Well Type					
	Depth:	Shallow □		Deep ■ 23		
	Dug □	Driving □		Tube ■ 23		
4-	Pump Locations					
	Inside Household ■ 1	In front of household ■ 5	Middle of the street ■ 3	In front of the canal ■ 14	Other □	
5-	Pump usage	Drinking ■ 13	Domestic ■ 10	Other □		
6-	Ownership	Private ■ 23	Public □	Other □		
7-	Construction year	Less than a year □	2 -3 years ■ 6	3 - 5 years ■ 12	6 – 10 years ■ 5	More than 10 yeas □
8-	No. of household served	1 -4 household ■ 1	4 -6 household □	6 -10 household □	More than 10 ■ 22	
9-	No. of operating hours	1 – 4 hour ■ 7	5 – 10 hour ■ 16	11– 15 hour □	16 –20 hour □	20 – 24 hour □
10-	Average No. of household and citizen served	Average No. of household served ■ 10 household 23		Average No of citizen per household served ■ 7 persons 23		
11-	Water consumption (l/p/day)	Less than 40 □	40 – 60 ■ 23	60 – 80 □	80 – 100 □	More than 100 □
	Extracted groundwater withdraw (m^3/d)	Less than 3 □	3– 4 □	4 – 6 ■ 23 3.5 (m^3/d)	6 – 8 □	More than 8 □
	Extracted groundwater withdraw (m^3/h)	Less than 1 □	1 – 2 ■	2 – 3 □	3 – 4 □	More than 4 □
12-	GW obstacles	Observed □		Not Observed ■ 23		
13-	Water Level	N.D (impossible to determine)				

Table 3.3 Photos of the inventory survey

 Inventory Survey	 Monitoring Wells (BH-N9)
 Measuring Groundwater Level	 Collecting Sample
 Water Quality Test (Simultaneous Survey)	 Sewage Tank (depth: approxi. 3m)
 Sewage Hole (depth: approx. 20m)	 Seepage of the Sewage

3.2 Groundwater monitoring of monitoring well

a) Time series change in groundwater level

Monitoring result of the groundwater level is shown in Figure 3.3 and Table 3.4. Water level at each canal was obtained from the daily data of Water Distribution Sectors (they monitor three times a day, and average value was applied in the study).

First of all, the groundwater head at each location have quite small diferences, having mostly within approximately 0.1m difference excluding the monitoring wells far from the construction site such as BH-N15 and BH-N16 (about 0.5m difference including those monitoring wells). Secondolly, change in piezometeric water level behaved almost the same manner in rise/drop tendency and its amount without any timelag. Those facts indicate the aquifer is confined aquifer affected by the canal water.

The day recorded highest groundwater level during the monitoring period was 27th July 2016 showing EL.43.71m at BH-N16 to EL.44.22m at BH-A3, and 18th January 2017 for the lowest groundwater level showing EL.41.55m at BH-N16 to EL.42.03m at BH-N14. Therefore, the seasonal change in groundwater head is 2.2m whereas the change in main canals are from 3.48m to 3.70m (3.70m at the upstream Ibrahimia, 3.48m at the downstream Ibrahimia and 3.65m at the downstream Bahr Yusef canals).

The water depth from the ground surface is 1.75m at least (BH-N13, 27 July 2016), and 8.82m at most (BH-N12, 18 January 2017).

During the winter closure season[1], the groundwater head at each monitoring well suddenly dropped corresponding to the sudden change in canal water level with a certain time lag. Therefore, focusing on the correlation between them can give the good insight into the behavior of the groundwater. Table 3.5 and Figures 3.4 to 3.7 show the correlation between each canal water level and the monitoring wells (BH-N7 and BH-N10) during the motnironing period with 0, 7, 14 and 21 days timelag. These table and figures indicate the groundwater head corresponds to the downstream canal water level (Ibrahimia and/or Bahr Yusef canals) rather than the upstream water level with approximately seven days timelag, showing the largest coefficient of the determination (R^2 values) in those conditions.

[1] Winter Closure: Ministry of Water Resource and Irrigation (MWRI) sets the maintenance period for irrigation facilities every year from the end of December to the middle of January

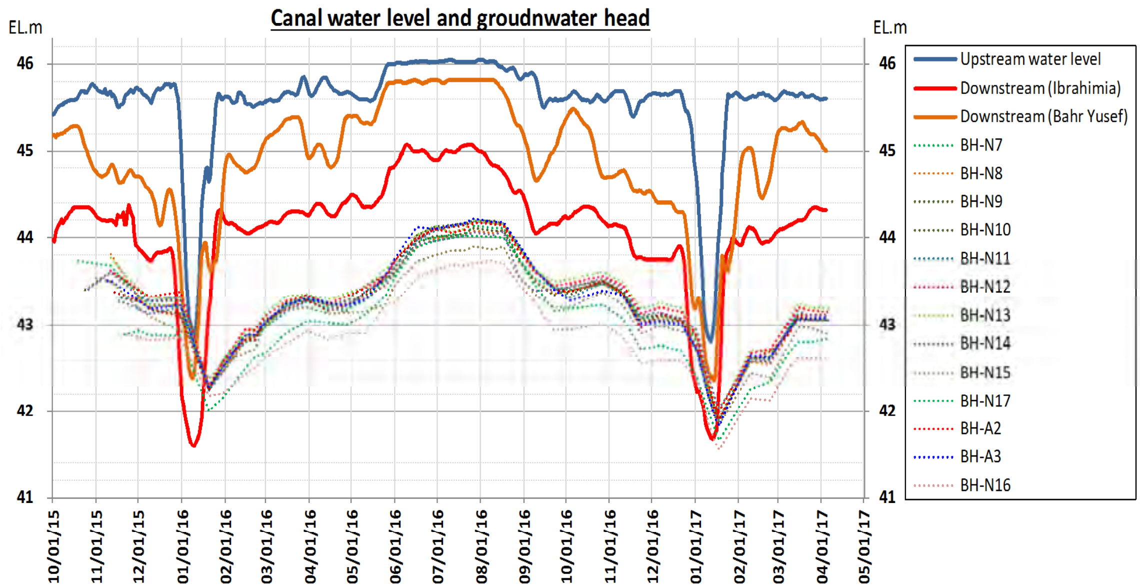


Figure 3.3 Time series change in water level for each monitoring well and canal (October 2015 until April 2017)

Table 3.4 Max. and Min. water level and water depth of monitoring wells and main canals

Monitoring Well / Canal	Max. Depth (m)	Min. WL (EL.m)	date		Min. Depth (m)	Max. WL (EL.m)	date
BH-N7	5.38	41.93	18/1/2017	～	3.17	44.14	27/7/2016
BH-N8	5.62	41.93	18/1/2017	～	3.46	44.09	17/8/2016
BH-N9	5.06	41.88	18/1/2017	～	2.83	44.11	27/7/2016
BH-N10	6.88	41.88	18/1/2017	～	4.56	44.20	27/7/2016
BH-N11	5.64	41.89	18/1/2017	～	3.34	44.19	27/7/2016
BH-N12	8.82	41.90	18/1/2017	～	6.54	44.18	27/7/2016
BH-N13	3.93	42.02	18/1/2017	～	1.75	44.20	27/7/2016
BH-N14	4.81	42.03	18/1/2017	～	2.77	44.07	17/8/2016
BH-N15	4.96	41.84	18/1/2017	～	2.90	43.90	10/8/2016
BH-N16	4.78	41.55	18/1/2017	～	2.60	43.71	10/8/2016
BH-N17	4.83	41.66	18/1/2017	～	2.47	44.02	27/7/2016
BH-A2	5.00	42.00	18/1/2017	～	2.83	44.17	27/7/2016
BH-A3	7.56	41.83	18/1/2017	～	5.17	44.22	27/7/2016
U/S Ibrahimia	-	46.08	23/6/2016	～	-	42.65	12/1/2016
D/S Ibrahimia	-	45.13	11/6/2016	～	-	41.60	12/1/2016
D/S Bahr Yusef	-	45.82	16/6/2016	～	-	42.17	18/1/2017

Table 3.5 Coefficient of deterimination values at each condition

Name	Canal	Time Lag			
		0 days	7 days	14 days	21 days
BH-N7	US Ibrahimia	0.601	0.710	0.728	0.312
	DS Ibrahimia	0.725	0.888	0.869	0.565
	DS Bahr Yusef	0.760	0.889	0.851	0.679
BH-N10	US Ibrahimia	0.596	0.687	0.719	0.305
	DS Ibrahimia	0.734	0.884	0.876	0.566
	DS Bahr Yusef	0.774	0.895	0.866	0.675

Timelag: 0 day

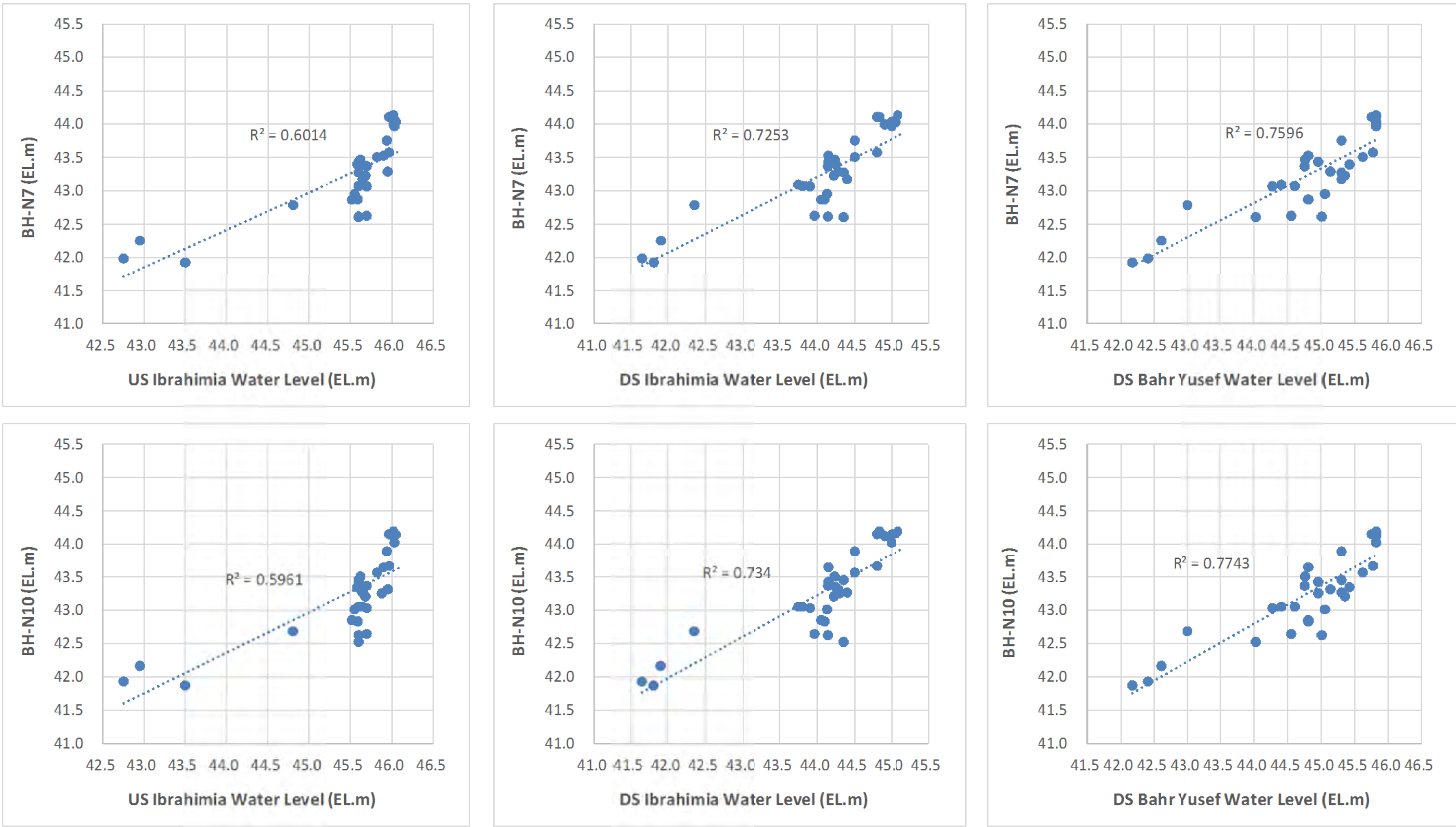


Figure 3.4 Correlation between the monitoring well (BH-N7, N10) and the main canal water level (0 day timelag)

Timelag: 7 days

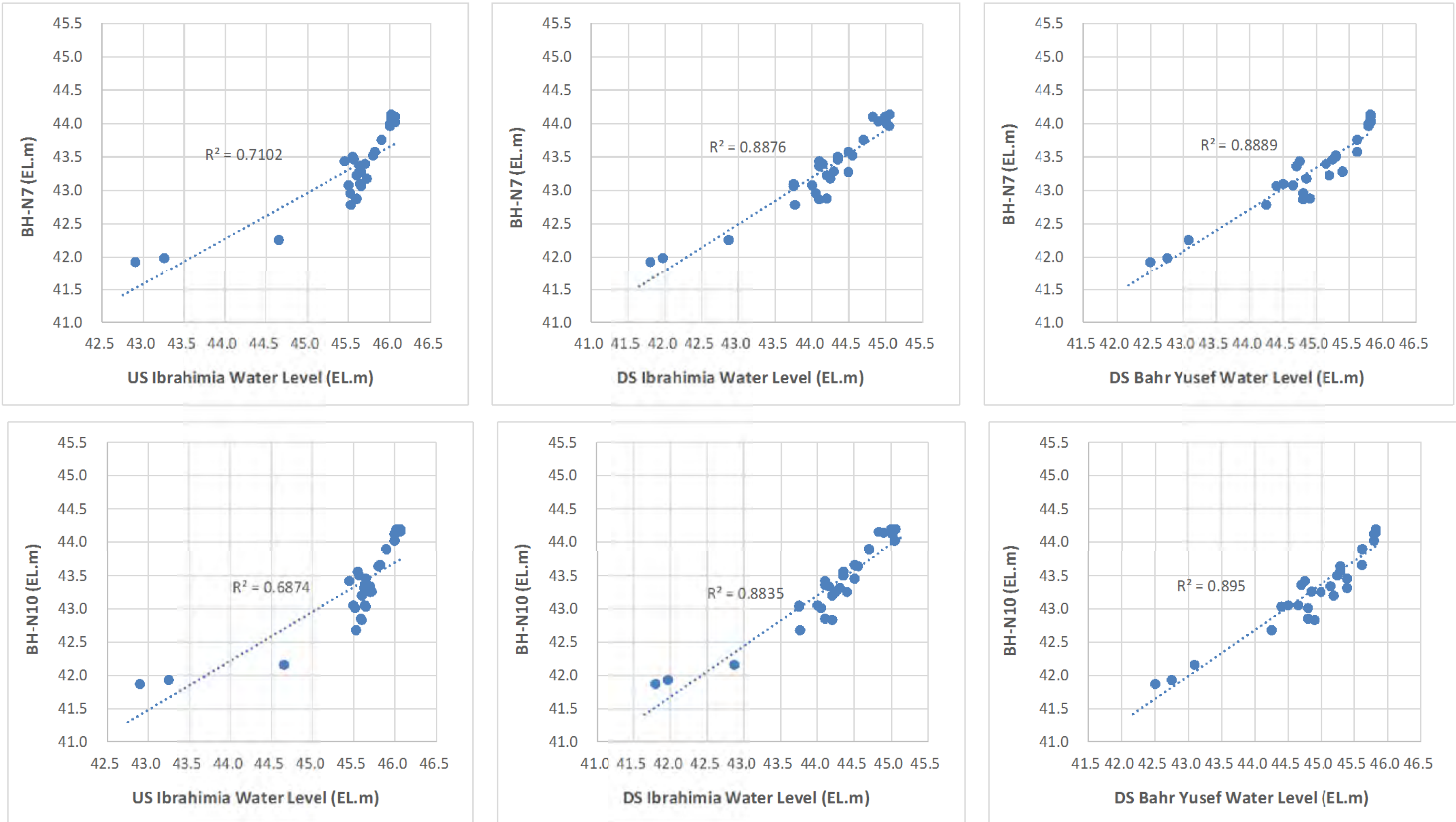


Figure 3.5 Correlation between the monitoring well (BH-N7, N10) and the main canal water level with 7 days timelag)

Timelag: 14 days

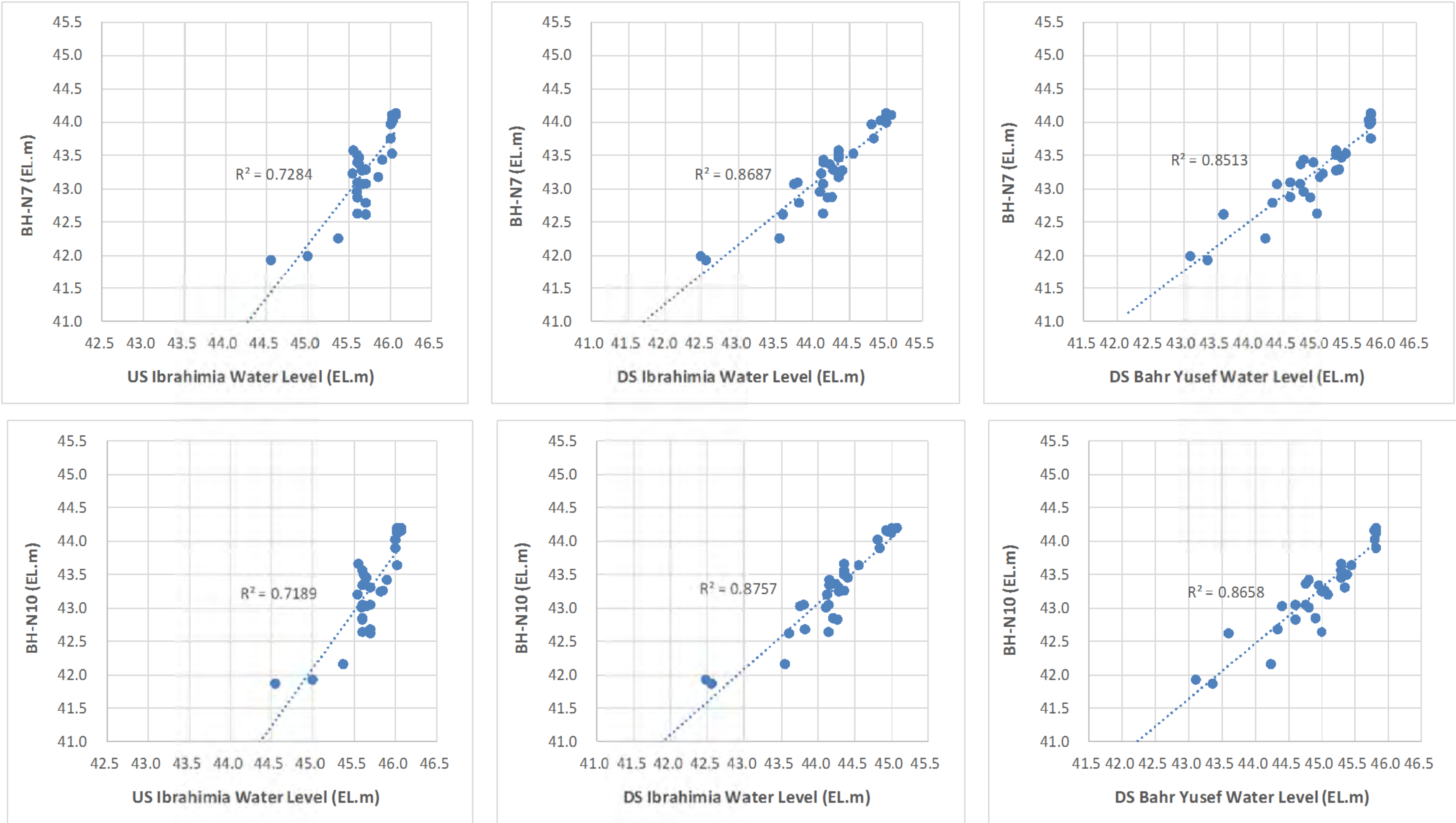


Figure 3.6 Correlation between the monitoring well (BH-N7, N10) and the main canal water level with 14 days time lag

Timelag: 21 days

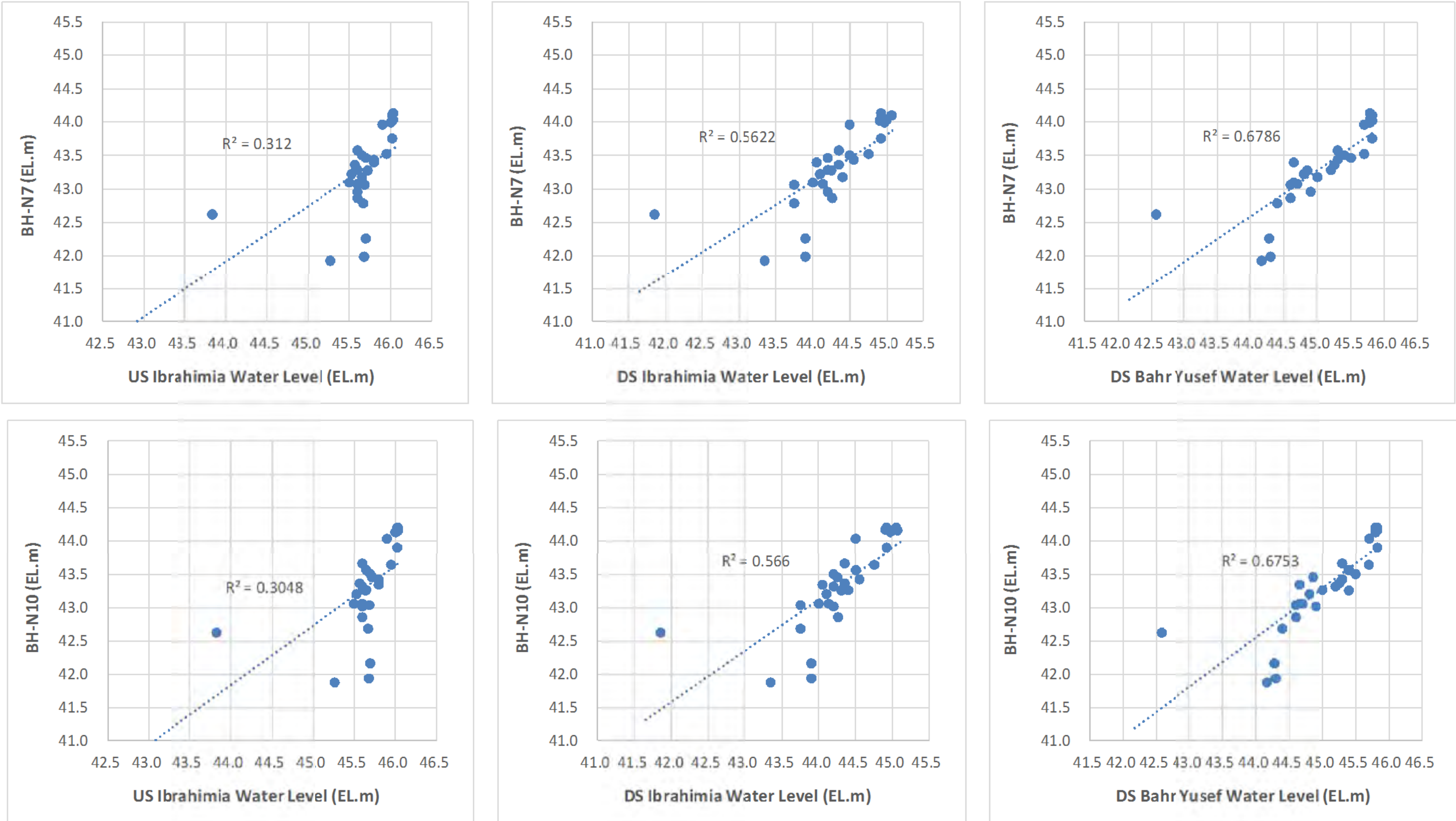


Figure 3.7 Correlation between the monitoring well (BH-N7, N10) and the main canal water level with 21 days timelag

Figure 3.8 shows the monitoring result broken down by location of monitoring wells (monitoring result for small canals such as Sahelyia canal are not shown in the figure during the winter closure because there is no discharge to those canals).

1) Upstream of DGRs (between Sahelyia, and Irad Delgaw canals)
   Water level at BH-N15 shows approximately 0.2m to 0.3m higher than BH-N16 all the time. Decrease in water level at BH-N15 and BH-N16 during the winter closure was 2.1m and 2.2m respectively from the highest water level whereas the cancanalal water level decreased by 3.7m during the winter closure (Upstream of the Ibrahimia Canal). Considering te result of correlation, even those monitoring wells are affected by the water level at the downstream Ibrahimia and/or Bahr Yusef canals rather than the upstream water level.
2) Downstream of DGRs (left bank 1, between Irad Delgaw and Abo Gabal canals)
   Water level at BH-N8 and BH-N14 is fluctuating at almost same level. Decrease in water level at BH-N8 and BH-N14 during the winter closure was 2.2m and 2.0m respectively when the canal water level decreased by 3.7m (Ibrahimia canal, Upstream of DGRs).
3) Downstream of DGRs (left bank 2, between Abo Gabal and Bahr Yusef canals)
   Water levels at the monitoring wells at the BH-N13 and BH-A3 are a little higher than the ones at BH-N7 and N9, showing 0.1m difference in almost all the time. This means the groundwater head does not correspond to the water level at the upstream canal, which also indicates the aquifer of the study area is confined. However, the sudden decrease in water levels at the Bahr Yusef canal during the winter closure may cause a reverse phenomenon in water level between groundwater level and canal water level, which indicates the aquifer may have the hydraulic connection each other.
4) Downstream of DGRs (right bank, between Ibrahimia and Sahelyia canals)
   Water levels at BH-N10, BH-N11, BH-N12 and BH-A3 is fluctuating at almost the same level, whereas BH-N17 located several hundreds meter away from surrounding canals has 0.2m to 0.3m lower water level than the other monitoring wells. During the winter closure, sudden decrease in water levels at the Ibrahimia canal clearly caused the reverse phenomenon in water level between groundwater level and canal water level (refer to Figure 3.9 which shows the change in water level focusing on the winter closure in 2016/2017). According to the result of geological survey, the nile silt layer is not covered in this area but covered by the fine sand. This indicates the aquifer could have the hydraulic connection each other.

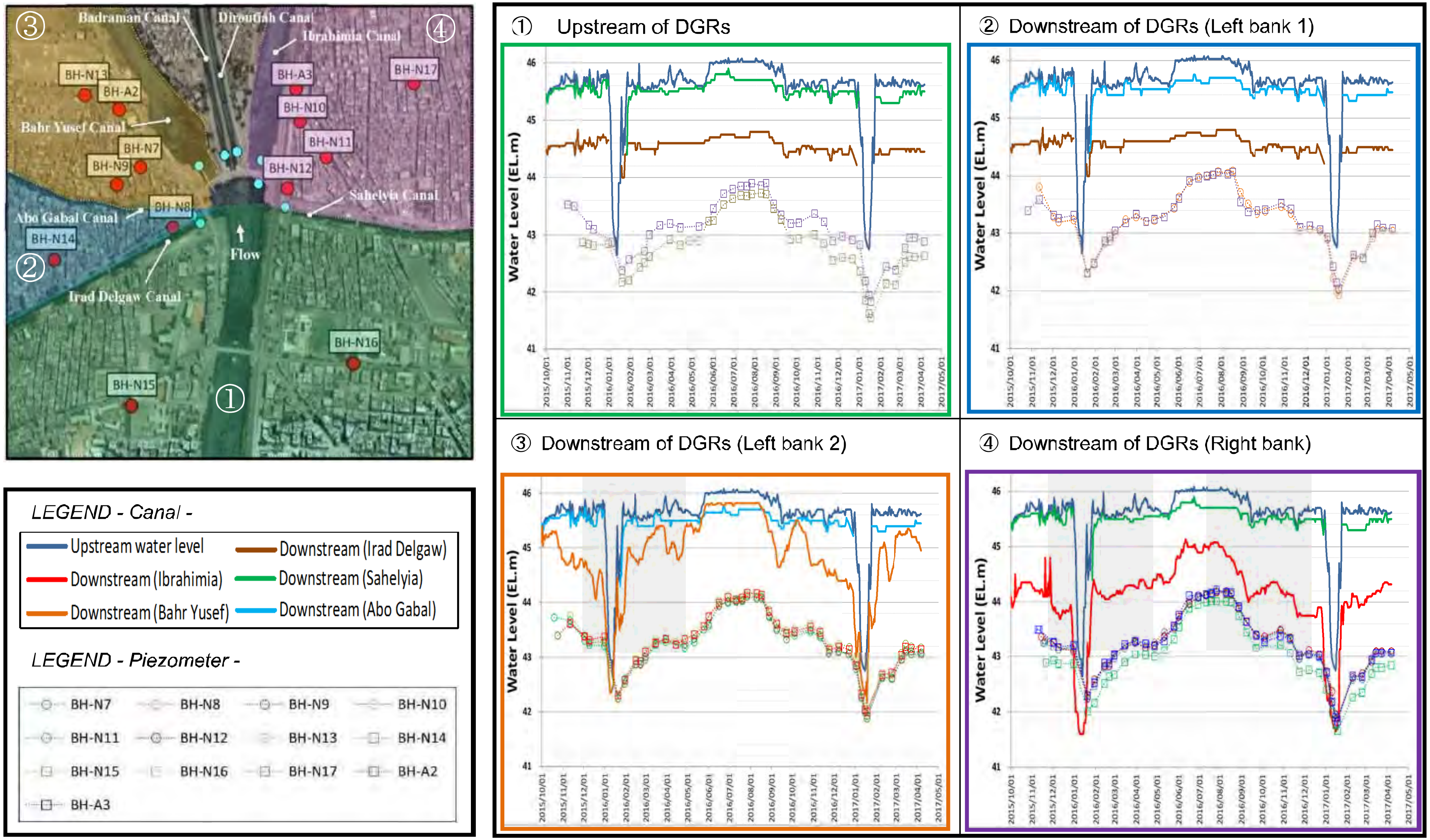


Figure 3.8 Time series change in water level for each monitoring well and canal for each area (October 2015 until April 2017)

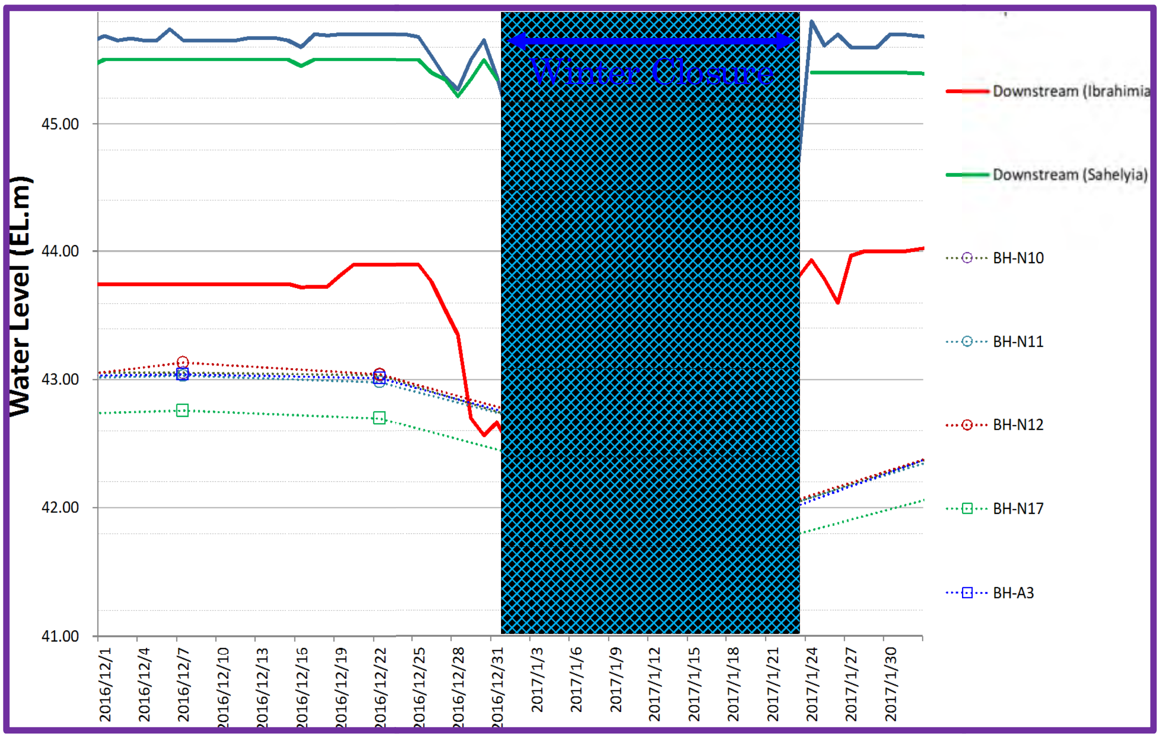


Figure 3.9 Change in water level at the monitoring wells located right bank of DS Ibrahimia canal (from 1 Dec. 2016 to 31 Jan. 2017 focusing on the winter closure period)

b) Time series change in the groundwater quality (EC, pH, and DO)

Monitoring results of Electric Conductivity (EC), pH and Dissolved Oxygen (DO) are shown in Figure 3.10 to 3.12.

The most remarkble characteristic in the groundwater quality is the monitoring wells near the right bank of DGRs especially BH-N10, N11 and N12. Especially for Electirc conductibity, it is outstandingly low compared to the samples from the other monitoring wells. On the other hand, those values are relatively close to the ones from the canal water (pH and DO have some fluctuations but show closer values in average). Although the tendency is not strong, BH-N13 on the left bank of downsream of Bahr Yusef canal and BH-A3 near the BH-N10 also show similar tendency. Those imply that the area where those monitoring wells are recharged by the surface water (Refer to Tables 3.6 to 3.8).

Regarding the water quality during the water closure where the blue hatched period in Figures 3.10 to 3.12, there is no significant change in any parameters compared to the data of the other period. Therefore, change in groundwater head does not have significant impact on the groundwater quality. The exception is found, however, in the values of electric conductivity especially at BH-N8, N9, N12, N17 and A3 which have some steep changes in EC during the monitoring period.

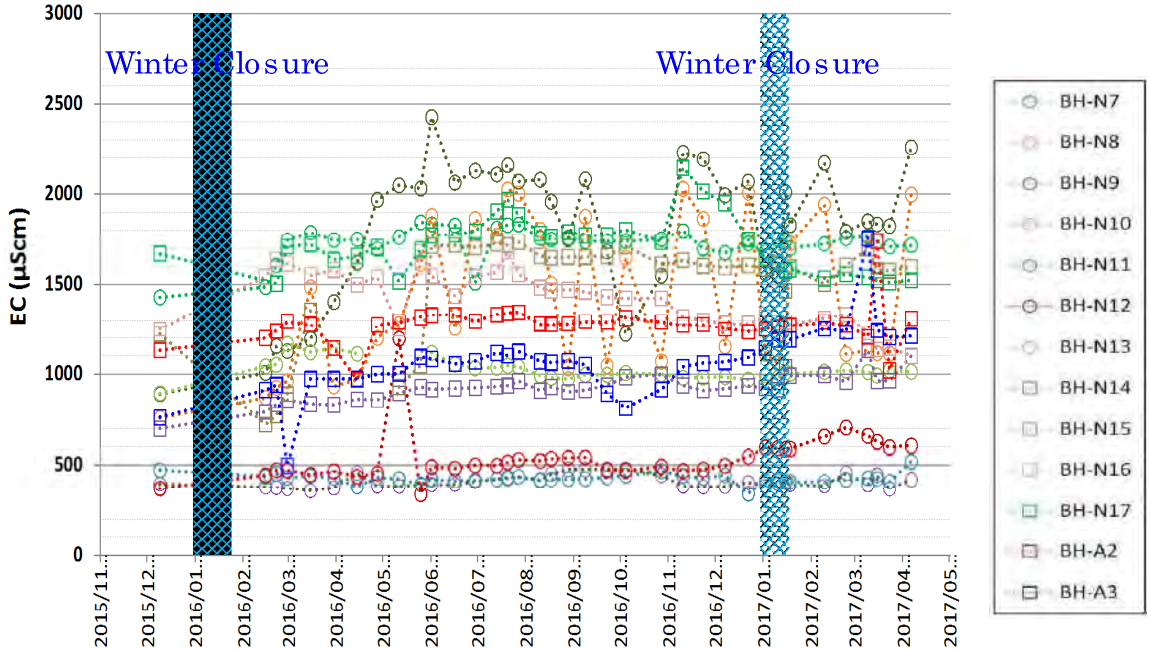


Figure 3.10 Time series change in Electric Conductivity (October 2015 until April 2017)

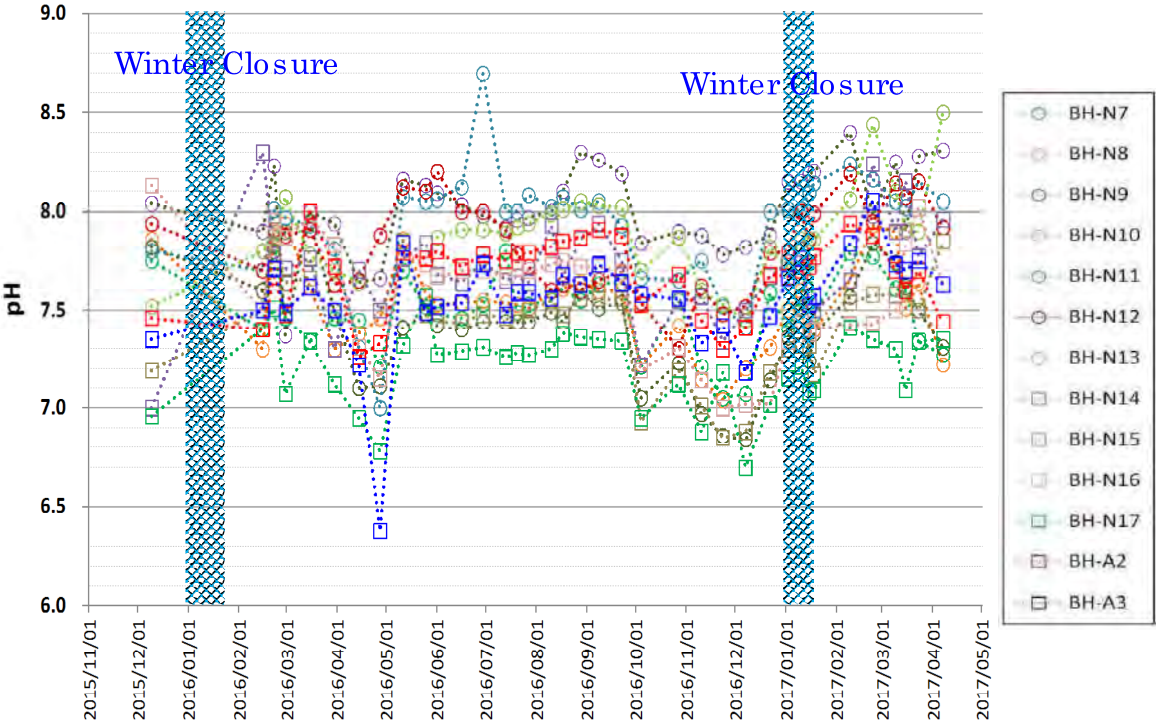


Figure 3.11 Time series change in pH (October 2015 until April 2017)

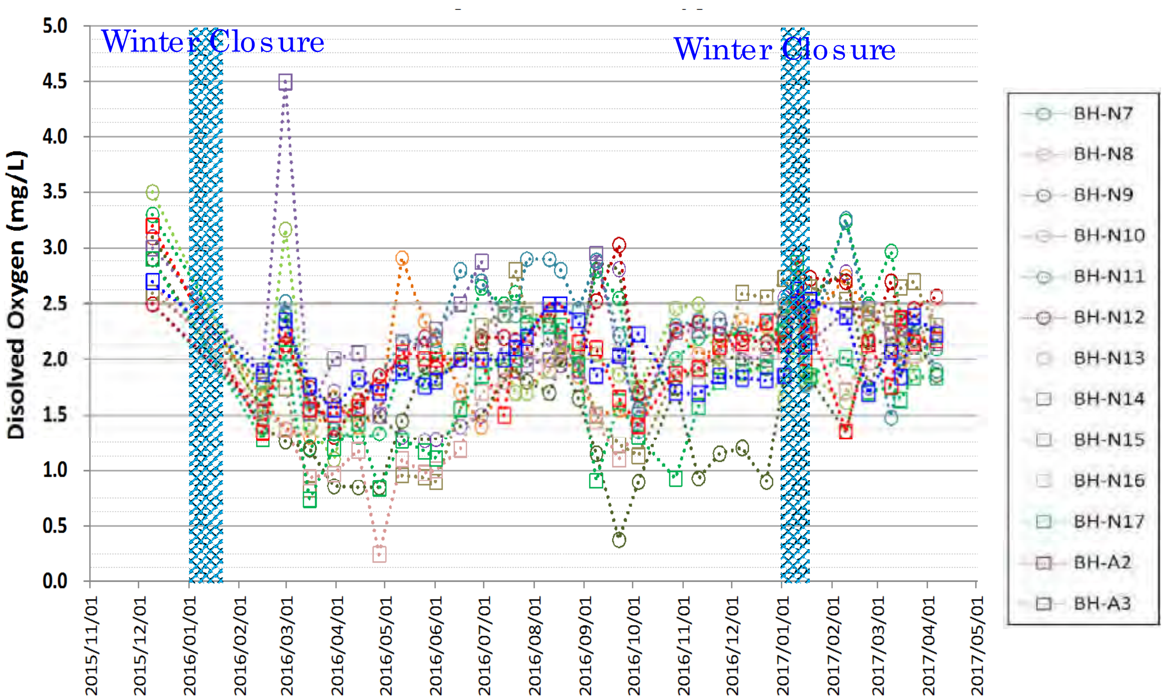


Figure 3.12 Time series change in Dissolved Oxygen (October 2015 until April 2017)

Table 3.6 Max. Min. and average of EC during the monitoring period

Monitoring Holes	Min. EC (μS/cm)	Date		Max. EC (μS/cm)	Date	Ave. EC (μS/cm)
BH-N7	1430	2015/12/9	~	1846	2016/5/25	1722
BH-N8	757	2015/12/9	~	2030	2016/11/10	1381
BH-N9	890	2015/12/9	~	2426	2016/6/1	1791
BH-N10	357	2016/3/15	~	478	2016/9/22	407
BH-N11	339	2016/12/22	~	519	2017/4/6	424
BH-N12	336	2016/5/25	~	1195	2016/5/11	537
BH-N13	895	2015/12/9	~	1167	2016/2/29	1021
BH-N14	698	2015/12/9	~	1130	2017/3/9	924
BH-N15	721	2016/2/15	~	1728	2016/7/13	1489
BH-N16	1098	2017/4/6	~	1680	2016/5/25	1400
BH-N17	1505	2016/2/22	~	2145	2016/11/10	1705
BH-A2	970	2016/4/16	~	1741	2017/3/15	1268
BH-A3	495	2016/2/29	~	1756	2017/3/9	1063
Canal	295	2015/12/9	~	354	2016/10/4	319

Table 3.7 Max. Min. and average of pH during the monitoring period

Monitoring Holes	Min. pH (-)	Date		Max. pH (-)	Date	Ave. pH (-)
BH-N7	7.05	2016/11/23	~	7.83	2016/2/22	7.50
BH-N8	7.04	2016/11/23	~	7.94	2016/2/29	7.53
BH-N9	6.84	2016/12/7	~	7.95	2016/3/15	7.43
BH-N10	7.37	2016/2/29	~	8.40	2017/2/9	8.02
BH-N11	7.00	2016/4/27	~	8.70	2016/6/29	7.93
BH-N12	7.30	2016/10/27	~	8.20	2016/6/1	7.84
BH-N13	7.45	2016/12/7	~	8.50	2017/4/6	7.88
BH-N14	7.00	2015/12/9	~	8.30	2016/2/15	7.70
BH-N15	6.85	2016/11/23	~	7.91	2016/2/22	7.42
BH-N16	7.00	2016/11/23	~	8.13	2015/12/9	7.56
BH-N17	6.70	2016/12/7	~	7.57	2016/5/25	7.20
BH-A2	7.26	2016/4/16	~	8.00	2016/3/15	7.67
BH-A3	6.38	2016/4/27	~	8.05	2017/2/23	7.55
Canal	8.57	2016/10/4	~	8.96	2015/12/9	8.76

Table 3.8 Max. Min. and average of DO during the monitoring period

Monitoring Holes	Min. DO (mg/l)	Date		Max. DO (mg/l)	Date	Ave. DO (mg/l)
BH-N7	1.20	2016/3/15	~	3.30	2015/12/9	2.21
BH-N8	1.30	2016/3/15	~	3.10	2015/12/9	2.05
BH-N9	0.38	2016/9/22	~	2.90	2015/12/9	1.59
BH-N10	1.27	2016/5/25	~	3.10	2015/12/9	2.01
BH-N11	1.35	2016/10/4	~	3.26	2017/2/9	2.23
BH-N12	1.30	2016/3/30	~	3.03	2016/9/22	2.21
BH-N13	1.10	2016/3/30	~	3.50	2015/12/9	2.03
BH-N14	1.50	2016/4/27	~	4.50	2016/2/29	2.26
BH-N15	0.83	2016/3/15	~	2.73	2017/1/2	2.02
BH-N16	0.25	2016/4/27	~	2.83	2017/1/10	1.73
BH-N17	0.74	2016/3/15	~	2.90	2015/12/9	1.69
BH-A2	1.34	2016/2/15	~	3.20	2015/12/9	2.01
BH-A3	1.55	2016/3/30	~	2.70	2015/12/9	2.04
Canal	5.10	2016/10/4	~	10.90	2015/12/9	8.27

3.3 Simultaneous monitoring survey

a) Spatial distribution of groundwater head

The simultaneous survey was implemented on 13th July 2016 as high water-demand season and 2nd January 2017 as low water-demand season. According to the result of the inventory survey described in the section 3.1, there are no wells for measuring the water level. Therefore, the groundwater head contour maps were created by the record of thirteen monitoring wells. The contour maps were created by the Surfer 13 and not considered the water level at each canal. Figures 3.13 to 3.16 show the groundwater head contour map in the study area on 14th April 2016, 27th July 2016 (highest level), 27th October 2016, and 18th January 2017 (lowest level) respectively[2]. At any time, they clealy show that the flow direction is generally toward the sountheast even though the direction is a little different in July (flowing toward more south direction) and in January (flowing toward more east direction) depending on the canal water level. This can be because the water level at the downstream spillway located on the southeast direction from DGRs is 1.0m to 3.0m lower than the groundwater head around DGRs (as shown in Figures 3.17 and 3.18).

The area where the pieometric surface shows higher is the downstream of Ibrahimia and Bahr Yusef canals (BH-N13, A2 for the Bahr Yusef canal and BH-N10 and N12 for the Ibrahimia). This implies that there are recharge sources of the confined aquifer somewhere at the downstream of those main canals (such as recharge from the canal, sewage tank, and sewage disposal hole). Therefore, in order to reproduce the actual distribution, some recharge sources must be considered.

b) Spatial distribution of groundwater quality

Figure 3.19 to 3.24 show the contour maps for EC, pH and DO on 14th April 2016, 14th July 2016, 27th October 2016, and 2nd January 2017 (lowest level) respectively. The most remarkable characteristic in the spatial distribution is the law EC around BH-N10, N11 and N12 at any time. These law EC values are similar to the surface water (canal: around 320μS/cm), which indicates there is the hydraulic connection between the surface water and groundwater around this area.

Furthermore, pH and DO values are also closer to the surface water compared to the other locations although this tendency is not such strong as the EC.

On the other hand, the other EC values showed 1,000 to 2500μS/cm, and the sampled groundwater smelled hydrogen sulfide. These facts indicate that the aquifer is also recharged by the sewage water. According to the Figure 3.20 which shows the EC distribution on 14th April when the EC of all the hand pump wells (including the ones out of the study aea was measured, the urbanized area has higher EC values hatching with red color.

[2] The date of the contour maps in July and January is different from the date of the Simulataneou survey (implemented on 13th July 2016 and 2nd January 2017), and therefore the data of the contour map for each water quality is also different from the contour maps for water level. This is partly because there is no significant relationship between groundwater level and its quality, and also because it is better to understand to show the date of highest and lowest water level.

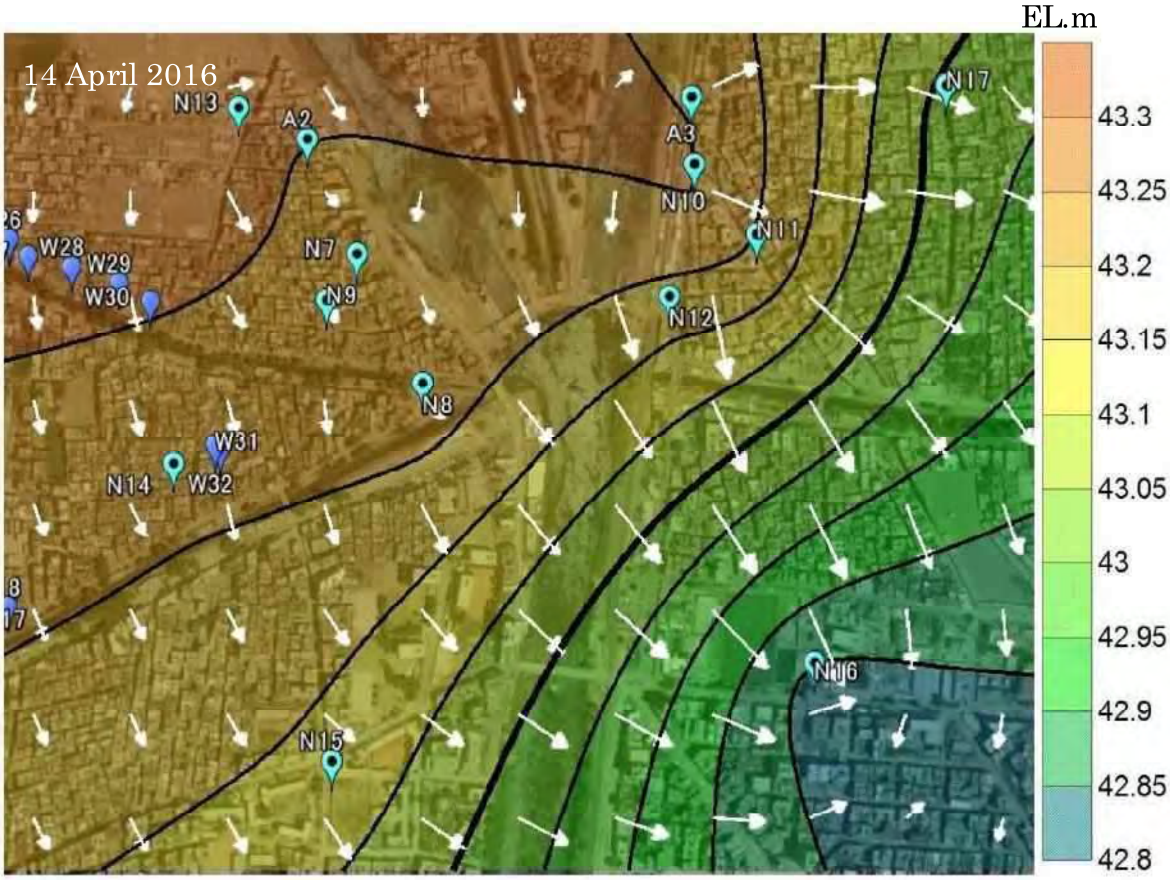


Figure 3.13 Groundwater head contour map on 14th April 2016

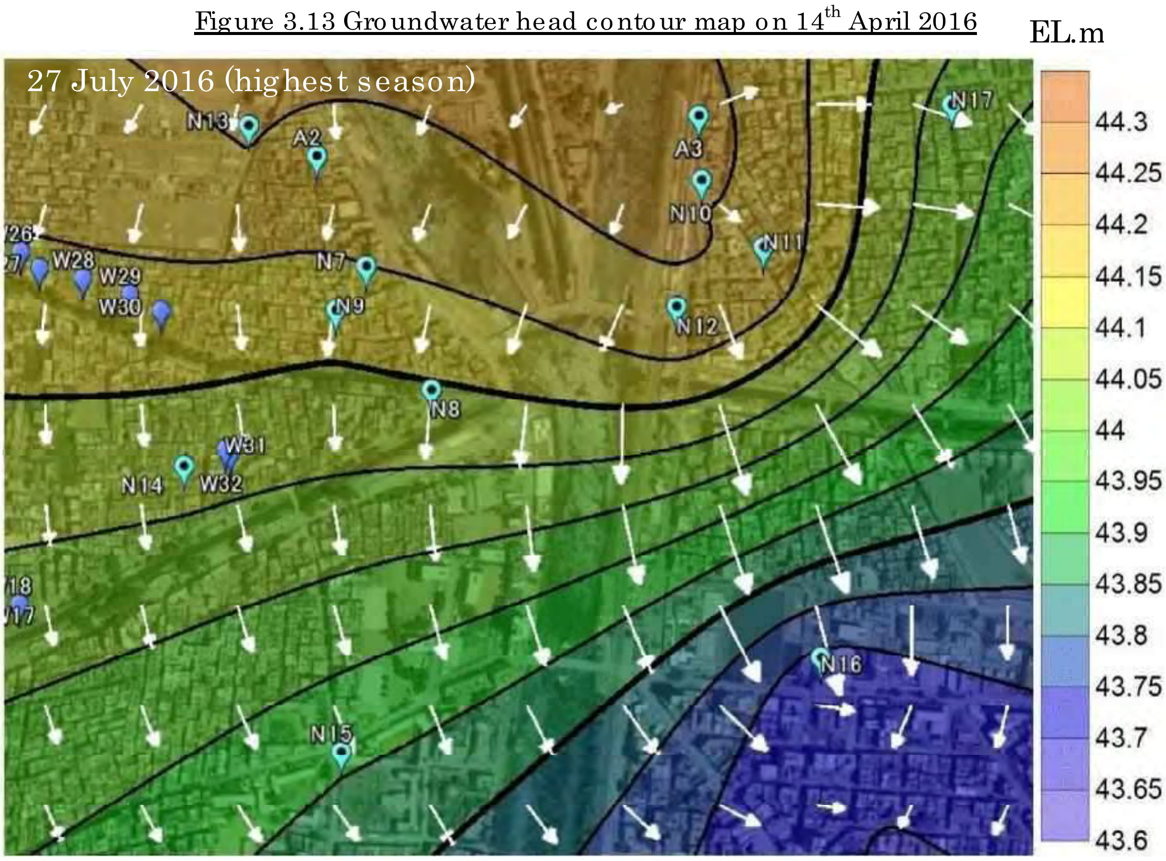


Figure 3.14 Groundwater head contour map on 27th July 2016

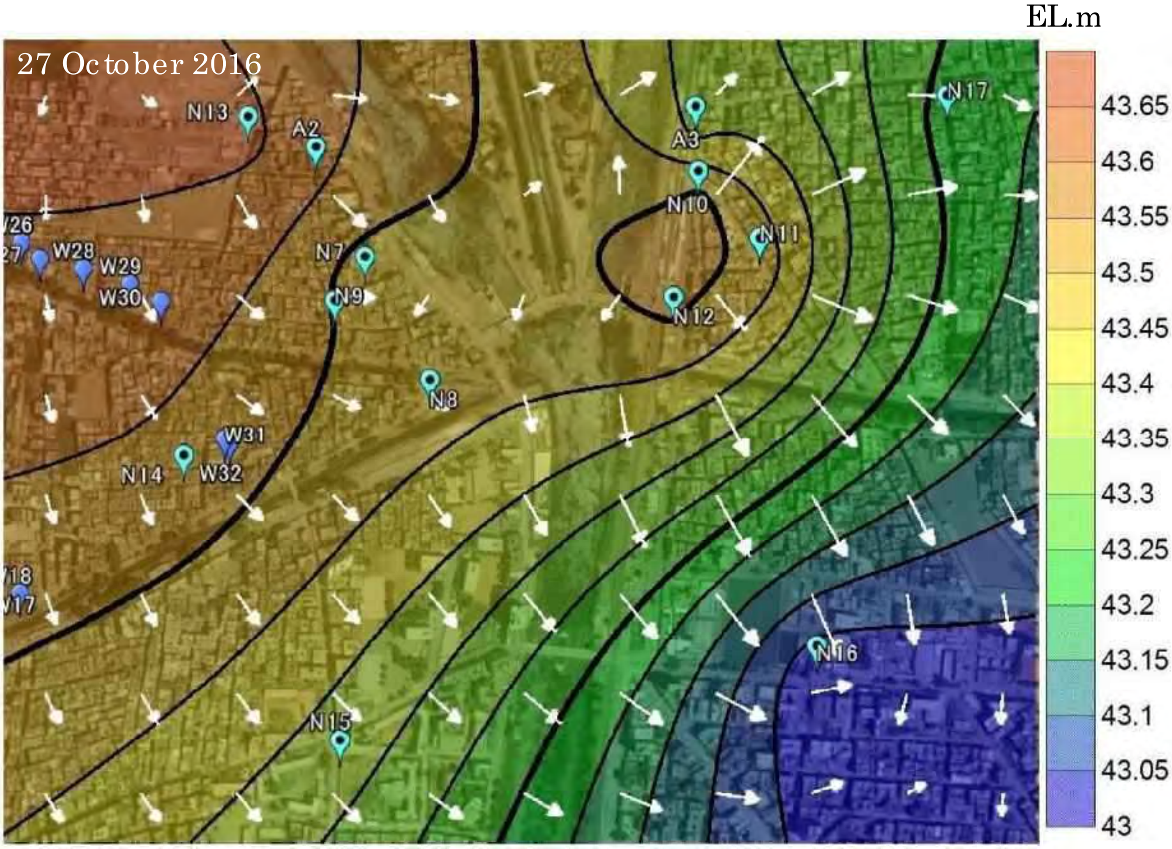


Figure 3.15 Groundwater head contour map on 27th October 2016

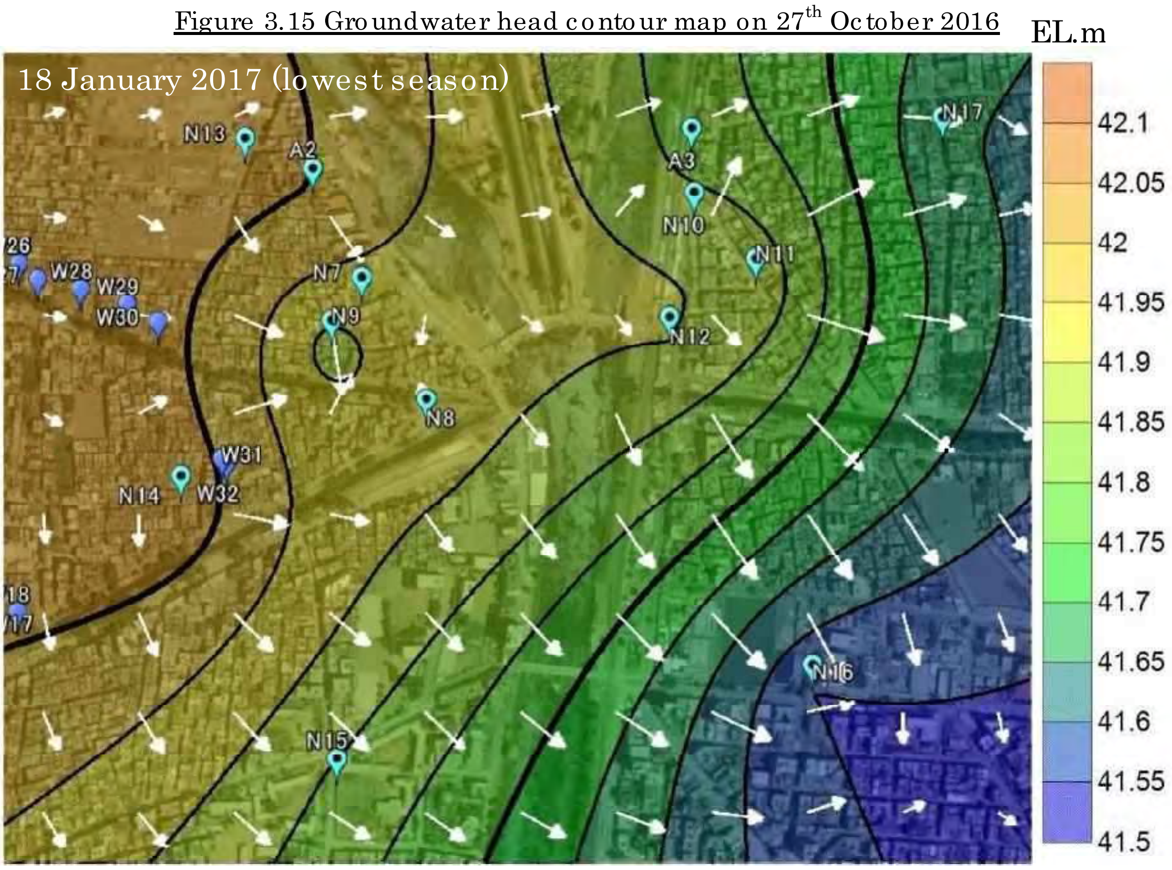


Figure 3.16 Groundwater head contour map on 18th January 2017

Figure 3.17 Location map of the Ibrahimia canal, spillway and the River Nile

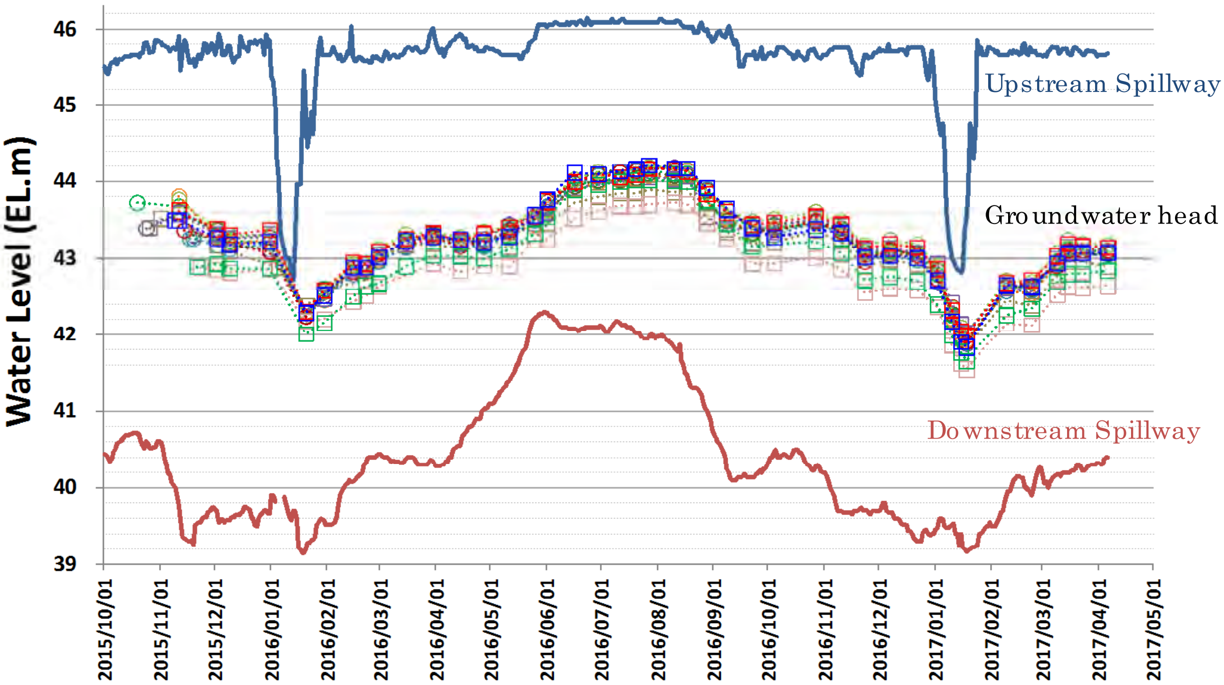
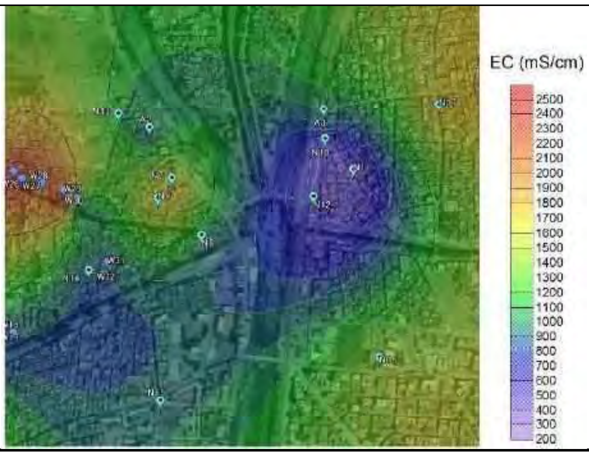
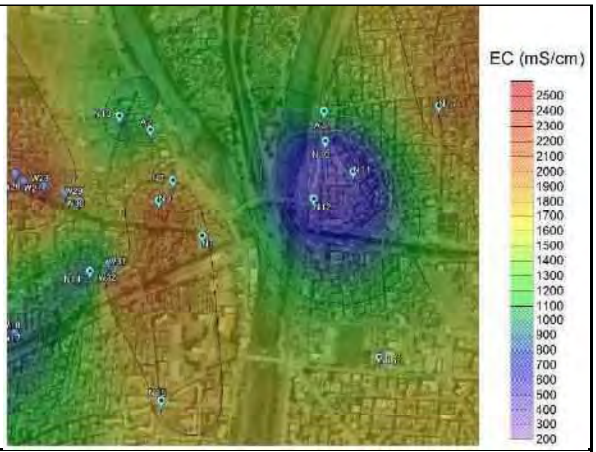


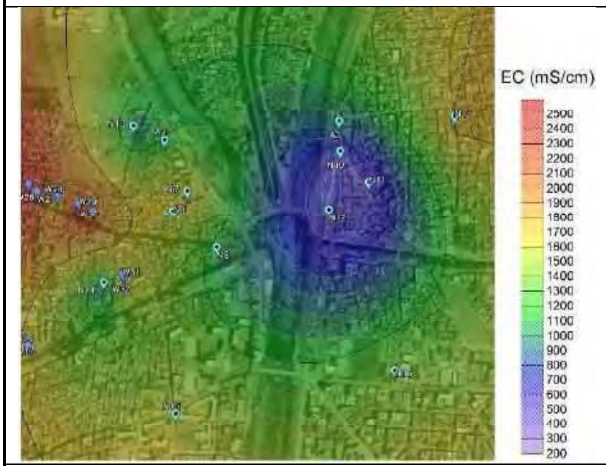
Figure 3.18 Relation between water levels of the US/DS spillway and groundwater head



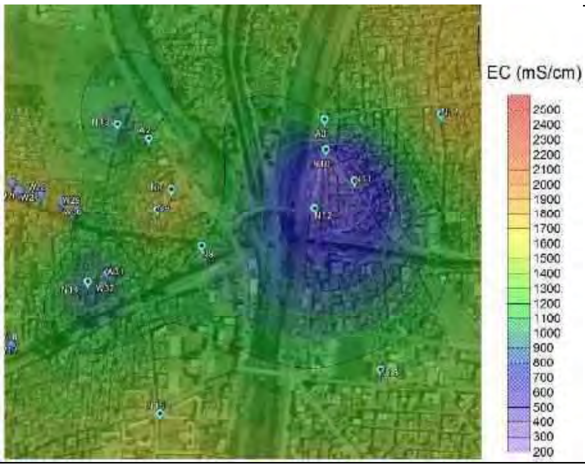
Date: 14th April 2016



Date: 13th July 2016



Date: 27th October 2016



Date: 2nd January 2017

Figure 3.19 Distribution map of EC

Figure 3.20 Distribution map of EC
(14th April 2016 including the pump wells outside of the study area)

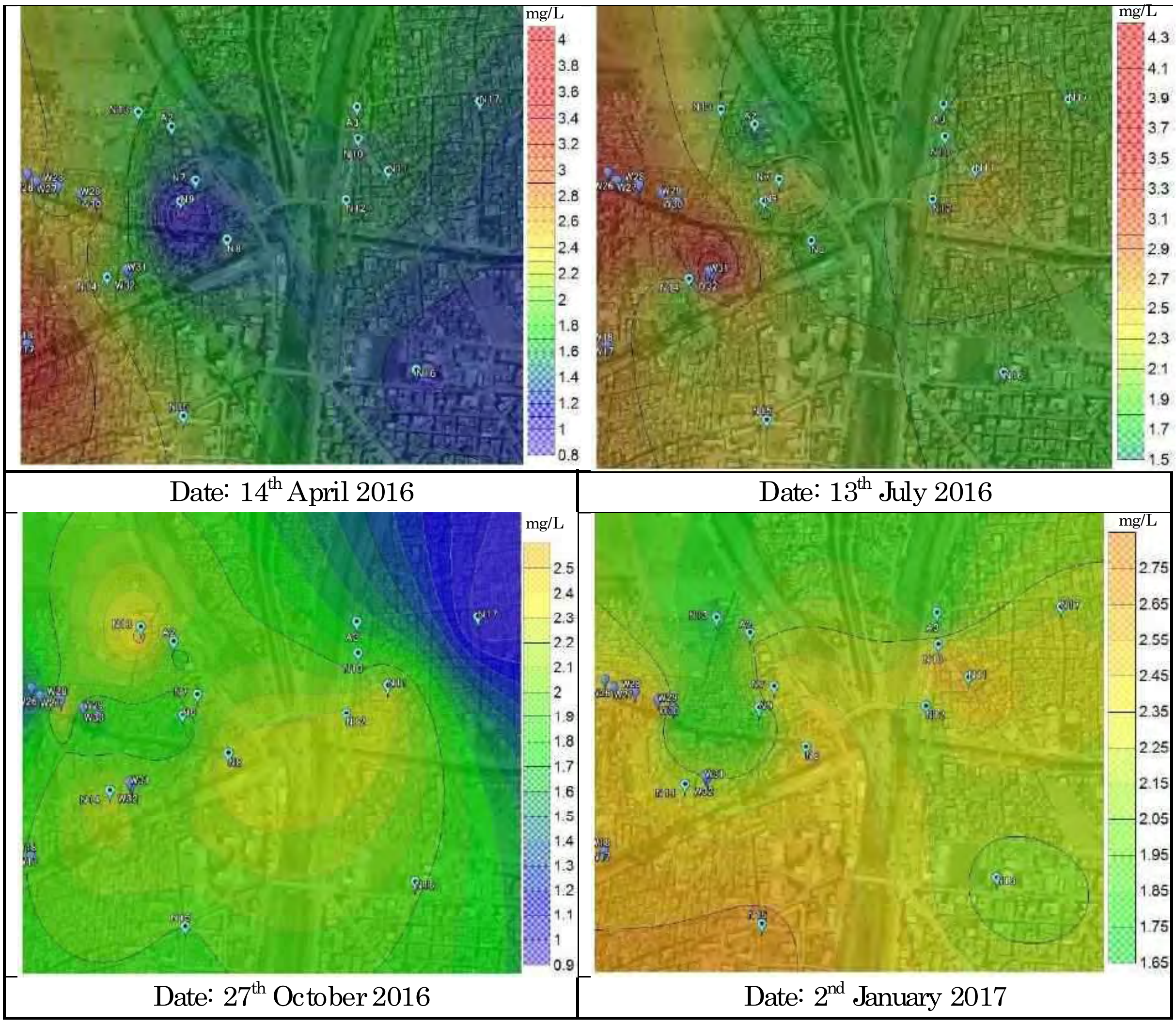
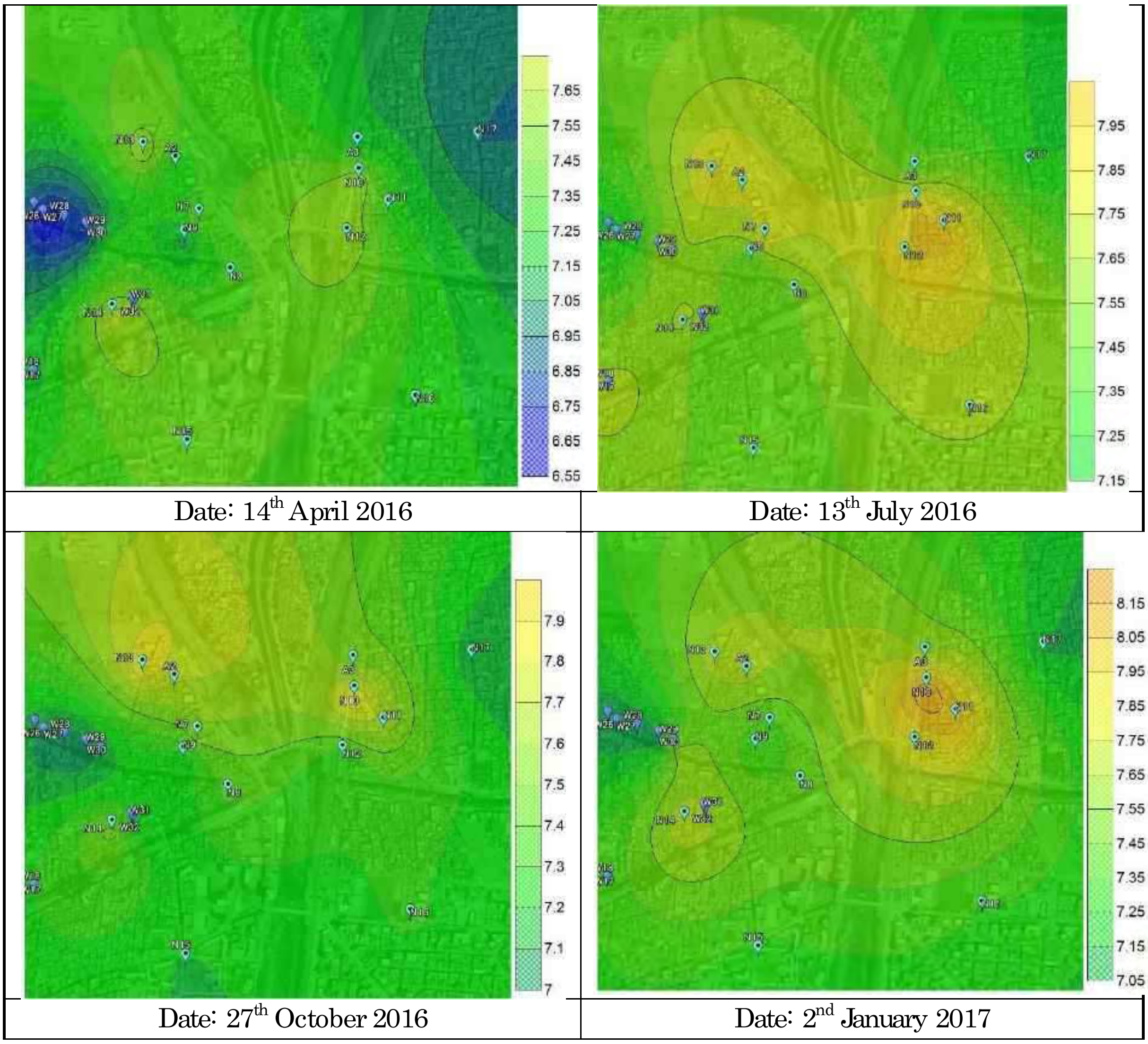


Figure 3.21 Distribution map of DO



Date: 14th April 2016 | Date: 13th July 2016

Date: 27th October 2016 | Date: 2nd January 2017

Figure 3.22 Distribution map of pH

3.4 Detailed water quality test

During the simultaneous survey implemented on 13th July 2016 and 2nd January 2017, the groundwater was sampled for the detailed water quality test. Location of the sampling was BH-N7 and BH-N10 which are located just left and right side of the axis of NDGRs (140m downstream from the DGRs, refer to Figure 2.1 for the location). The result of the quality test was shown in Table 3.9.

The following 4 findings show that groundwater at BH-N7 is more contaminated by sewage more than the one at BH-N10.

1) It can be evaluated that BH-N7 has twice more contaminated by the organic pollutants than BH-N10 based on the COD and BOD.
2) Sodium (Na) and Chloride (Cl) are good indicators for the sewage pollution in this geological condition. The amount of those ions at BH-N7 is five times more than the one at BH-N10, which indicates the sewage affects more into BH-N7.
3) Sulfur amount showed high value at both monitoring wells, which makes the unpleasant odor of hydrogen sulfide. Considering the location of the sampling site (urbanized city on the Nile flood area), such high amount of Sulfur is derived from the sewage from each household which makes the aquifer in reduced state.
4) Coliform amount at BH-N7 is more than 3 times more in total coliform and 10 times more in fecal coliform at BH-N10 on 13th July 2016, which indicates the groundwater at BH-N7 was more contaminated by sewage than the one at BH-N10.

In addition, 4 more following remarks should be noted in comparison with the prescribed values in the Egyptian standards for drinking water and domestic uses (2007)[3].

5) Turbidity at both monitoring wells, TDS at BH-N7, and dissolved Na and Cl at both monitoring wells were out of the drinking water standards in physical & (hydro)chemical property.
6) More than three times amount of Mn from the standards was detected at BH-N7 (almost the standard value at BH-N10 as well), which can cause a serious health problem in human body for dringking.
7) More than 45 times amount of NO2 from the standards was detected at BH-N10 on 13th July 2016.
8) Coliform amount value is considerably high at both monitoring wells. No fecal coliform was detected in the groundwater sampled on 2nd January 2017, which may be because of the low temperature that is not suitable environment especially for fecal coliform.

Thus, the groundwater at both monitoring wells is suitable to utilize as drinking water because it is clearly affected by sewage especially at BH-N7.

[3] Decree of Health Minister (No. 458) / (2007). Egyptian standards for drinking water and domestic uses

Table 3.9 Result of detailed water quality test

Item		Unit	Egyptian Standard*	BH-N7		BH-N10		Remarks
				13 Jul. 2016	2 Jan. 2017	13 Jul. 2016	2 Jan. 2017	
Physical & Chemical Property								
1	Temperature	°C	-	25.0	23.5	24.6	22.9	-
2	pH	-	6.5 - 8.5	8.0	7.4	8.0	8.2	-
3	EC	mS/cm	-	1.714	1.68	0.424	0.383	Electric Conductivity
4	Turbidity	NTU	1	5	8	13	3	-
5	TDS	mg/L	1000	1098	1175	271	258	Total Dissolved Solids
6	TSS	mg/L	-	2	3	2	3	Total Suspended Solids
7	COD	mg/L	-	110	138	40	53	Chemical Oxygen Demand
8	BOD	mg/L	-	160	200	63	80	Biological Oxygen Demand
9-1	CO_3	mg/L	-	0	0	0	0	Carbonate
9-2	HCO_3	mg/L	-	574	220	178	138	Bicarbonate
10	TA	mg/L	-	574	220	178	138	Total Alcalinity
Hydro-chocmial Property								
11	Ca	mg/L	200	103	120	34	31	Calcium
12	Mg	mg/L	150	38	17	11	10	Magnesium
13	Na	mg/L	200	220	200	35	28	Sodium
14	K	mg/L	-	12	16	4	6	Potassium
15	Cl	mg/L	250	259	265	28	21	Chloride
16	SO_4	mg/L	250	20	210	13	21	Sulfate
Trace Element & Heavy Minerals								
17	NO_3	mg/L	44	0.71	0.3	3.47	< 0.2	Nitrate
18	NO_2	mg/L	0.02	< 0.2	< 0.2	0.91	< 0.2	Nitrite
19	PO_4	mg/L	-	< 0.2	< 0.2	< 0.2	< 0.2	Phosphate
20	S	mg/L	-	6.81	70	4.24	7	Sulfur
21	Cr	mg/L	0.050	0.001	0.004	0.001	< 0.001	Chromium
22	Cu	mg/L	2.0	0.031	0.020	0.027	0.015	Copper
23	Fe	mg/L	0.3	0.080	0.162	0.054	0.119	Iron
24	Mn	mg/L	0.4	0.163	1.515	0.238	0.445	Manganese
25	Ni	mg/L	-	0.033	0.012	0.004	< 0.001	Nickel
26	Pb	mg/L	0.01	< 0.001	< 0.001	< 0.001	< 0.001	Lead
27	Zn	mg/L	5.0	0.010	0.013	0.004	0.005	Zinc
Others								
-	Total Coliform	CFU/100ml	N/D	1.4E+05	4.4E+03	5.0E+04	1.2E+03	-
-	Fecal Coliform	CFU/100ml	N/D	2.0E+05	N/D	2.0E+04	N/D	-

* Egypt Standards according to the Minister of Health decree Number (108) for 1995 and (458) for 2007

4 Conclusion and Recommendations

4.1 Conclusion

The groundwater monitoring was implemented to reveal the hydraulic behavior of the groundwater, and the following presumptions were derived from the results of time series groundwater level, EC, pH and DO data.

1) In July, as the high-water demand season, the piezometeric surface showed the highest values (depth from the surface fround is 1.75m at least in the study area). It is noted, however, the groundwater level in the survey area is groundwater head which means the water table does not exist until the monitoring well connects to the aquifer (sand layer).
2) The aquifer clearly has the hydraulic connection to the surface water level (DS of Ibrahimia and/or Bahr Yusef canals) with approximately 7-day lag, which implies that rise in groundwater level by the construction of NDGRs will cause the rise in groundwater level.
3) The aquifer is recharged around BH-N10, N11, N12, and maybe from the downstream of BH-N13 as well because of the result of the water quality test (showing relatively similar values in EC, pH and DO).
4) The aquifer is also recharged by the sewage from sewage tanks or sewage holes due to insufficient sewage system.
5) Groundwater flows mainly toward southeast direction (to the direction of the downstream spillway).
6) The water quality seems nothing to do with groundwater level or canal water level.
7) Substantial concentration of sulfur shows the aquifer is in a reduced state, which implies the sewage pollution to the aquifer.
8) Groundwater is not suitable for drinking water because it can cause health problem for human body mainly due to the presence of coliform and excessive amount of Manganese.

4.2 Recommendations

・Groundwater modelling should be executed based on the monitoring results, which can consider the canal water level better.

・In order to confirm the hydraulic connection between surface water and aquifer, detailed water quality is recommended to be carried out to compare the result of BH-N10 where the direct hydraulic connection between aquifer and surface water may exist.

・It is clear that the pollution of the groundwater was caused by the sewage intrusion to the aquifer. Through the field monitoring survey, it was found that mulfunction of the sewage treatment also caused the wet surface with unpleasant smells. Although this type of ground surface seepage has nothing to do with the effect by the construction of NDGRs, the sewage must be properly treated by the responsible ministry to avoid surface seepage.

・A part of causes for wet ground was also by the malfunction of the water supply system. It must be improved not only to prevent the wet ground, but also to avoid drinking the groundwater which is not suitable for drinking.

・According to the EIA report, the monitoring will be kept doing during/after the construction stage. All the monitoring wells are located in the urbanized area, so they are easy to be damaged because of the heavy traffic and mischief by residents (refer to the Table 4.1 for the maintenance record in this study). Therefore, it is required to keep checking their condition (once in one or two months) and take the appropriate maintenance and additional protection work if necessary in order to avoid the degradation of the monitoring wells and to keep the accuracy of modeling result.

Table 4.1 Maintenance record of the monitoring wells

Date	Countermeasure for protection and its result	Photo
3rd November 2015	【Countermeasure for protection】 Installed the casing protection for each monitoring well in the same manner of specifications of the survey.	
	【Result】 Garbage collection truck tore the protection off when it collected the garbage, and garbage was stuck in the monitoring well.	
19th November 2015	【Countermeasure for protection】 Installed the iron frame protection for each monitoring well as additional protection for the garbage truck.	
	【Result】 Garbage collection truck tore the protection off when it collected the garbage.	
4th January 2016	【Countermeasure for protection】 Installed iron made thick pipe with protection stones to be easily aware of the existence of monitoring well (only for BH-N15).	 After Broken 
	【Result】 Garbage collection truck broke all the protection, which seems to be intentional.	
3th May 2016	【Countermeasure for protection】 Installed the heavy manhole as lid to protect from the heavy cars except for the BH-N7, N14 and A2 which are relatively safe against the heavy cars	
	【Result】 Even though the manhole was installed, clogging with gravels which seems to be caused by the mischief happen at BH-N13 and BH-N15 occurred.	
14th May 2016	【Countermeasure for protection】 Removal of the clogging gravels with a pump.	 
	【Result】 There is no trouble for monitoring after this protection.	