OPERATIONAL MANAGEMENT SYSTEM FOR BAHR WAHBA CANAL

M.K. Mahmoud

Researcher, Hydraulics Research Institute, National Water Research Center
Hydraulics Research Institute, Delta Barrage, P. O. Box 13621, Egypt
E-mail: Kamel202@hotmail.com , M.Kamel@hri-egypt.com

ABSTRACT

The main objective of this paper is to set up an adequate system to operate Bahr Wahba Canal. This well leads to an efficient use of irrigation water that leading to higher crop yields, reduce of operation costs in particular the cost of energy needed for pumping and sustainable management of salinity to prevent loss of agricultural land.

Bahr wahba takes its water from the right side of Bahr Yousef upstream Hawarrah head regulator. The physical properties of collected water samples have been analyzed at 43 locations. Most of these measurements were carried out near the vicinity of the mixing zone at the confluence of escape of El Bats drain and Bahr Wahba just upstream Abd El-Hady weir. The physical properties of water (salinity, B.O.D) in the reach from the intake till 30 m upstream El Bats drain are within the standard values according to the environment law No.48 year 1982 while down stream the drain, these values are exceeded the allowable limits.

A hydrodynamic model was set up to test the hydraulic performance of the canal under the design conditions, extreme conditions of the discharges and to check the effect of different discharge ratios between fresh water and saline water on the canal performance. The model have been calibrated and verified by using the measured field data. The model has been operated to check the maximum capacity of Bahr Wahba, to obtain the water levels at the off takes under different flow conditions and to obtain the volume of fresh water required in the mixing zone to reduce the salinity within the allowable limits.

The Study results indicated that the additional amount of fresh water required for Bahr Wahba per year to keep the maximum salinity within the allowable limits is 30.32 M.C.M. The capacity of Bahr Wahba is enough to safely carry the maximum discharge from Bahr Yousef, which is 19.20 m3/s. A telemetry and voice communication systems are recommended for optimal operation and best water management. The project of supplying El-Giza canal from El mouhit drain should be completed to increase the water budget for El Faioum Directorate to cover the additional fresh water for Bahr Wahba. It is recommended to have a remote station for water level measurements to continuously monitoring the water levels in Lake Qaron.

INTRODUCTION

Bahr Wahba is located at the left bank of Bahr Youssef Canal, upstream Hwarrah Regulator. The main objective of this paper is to carry out all hydraulic investigations, which is necessary to set up of an adequate system to operate Bahr Wahba, which is envisaged will contribute to:

- Efficient use of irrigation water leading to higher crop yields.
- Reduction of operation costs, in particular cost of energy needed for pumping.
- Sustainable management of salinity and thus prevention of loss of agricultural land.

BATHYMETRIC SURVEY

The Bathymetric survey covered a reach of 45.0 km of Bahr Wahba. It was carried out using the Differential Geographical Positioning System (DGPS) to measure the global coordinates of the measuring points and Echo sounder to measure the water depths at the measuring points. The bathymetric survey was carried out in cross sections normal to the flow direction; the distance between each two cross sections was approximately 50-100 m.

The bathymetric of each cross-section was carried out through two methods:

- Manually using staff gauge and the total station for the canal banks and up to water depth of 0.5 m.
- Echo sounder (DSF-600 Digital Survey Fathometer) installed in a rubber boat for the rest of the cross-section.

1. Flow Velocity Measurements

The Flow velocity measurements, using Bray Stock Current meter, has been carried out at ten cross-sections. The measurements were taken at 7 vertical uniformly distributed along each cross section. The location of the cross sections is shown in Figure (1).

2. Bed Sampling

The bed samples were collected at the same cross sections of the velocity measurements at three points uniformly distributed along each cross section.

3. Local Hydrography

Bahr Wahba at the study area has about seven bends and a number of hydraulic structures. The canal width in this area varies between 25 m and 15 m, while the mean water depth is varies between 3.4 m and 1.0 m. The discharge and water levels at Bahr Wahba controlled by Hwarra Regulator at Bahr Youssef and the discharge of El-Bats pumping station, which is located just upstream Abd El-Haddy weir. The following data were collected from the Ministry of Water Resources & Irrigation (MWRI):

Table (1) Monthly Discharge of Bahr Wahba and El-Bats Pumping Station, 1998&1999.
Table (2) Monthly Average Salinity of Bahr Wahba, El-Bats Pumping Station, and Downstream Abd El-Haddy Weir, 1997, 1998 & 1999.
Table (3) Measured Salinity Upstream and Downstream Abd El Hay Weir.

Table (1) Monthly Discharge of Bahr Wahba & El Bats Pumping Station 1998 & 1999

Month	1998		1999	
	Abd El Hady (MCM)*	Bats Pump Station (MCM)*	Abd El Hady (MCM)*	Bats Pump Station (MCM)*
Jan.	5.16	1.64	4.52	3.06
Fab	6.16	3.32	8.03	6.84
Mar.	7.34	6.21	8.83	7.98
April	7.83	5.64	8.4	6.59
May	8.37	3.74	8.72	5.49
June	10.39	5.53	8.87	6.67
July	10.01	7.31	9.1	7.96
Aug.	9.52	7.22	9.46	8.23
Sep.	10.48	6.17	8.53	6.13
Oct.	11.01	4.74	8.97	6.27
Nov.	9.69	5.17	8.6	5.84
Dec.	8.98	5.19	9.09	5.72
Sum.	**104.63**	**61.89**	**101.11**	**76.78**

Table (2) Monthly Average Salinity of Bahr Wahba, El Bats Pumping Station and D.S Abd El Hady Weir, 1997, 1998 and 1999

Month	1997			1998			1999		
	Bats (g/l)	**U.S Abd El Hady (g/l)**	**D.S Abd El Hady (g/l)**	**Bats (g/l)**	**U.S Abd El Hady (g/l)**	**D.S Abd El Hady (g/l)**	**Bats (g/l)**	**U.S Abd El Hady (g/l)**	**D.S Abd El Hady (g/l)**
Jan.		Closure Period		1.77	0.9	1.73	1.68	0.8	1.52
Feb.	1.32	0.59	1.11	1.25	0.68	1.12	1.39	0.77	1.25
Mar.	1.4	0.61	1.18	1.44	0.7	1.36	1.55	0.7	1.44
April	1.21	0.61	0.86	1.04	0.55	0.87	1.22	0.64	1.12
May	1.27	0.51	1.03	1.05	0.52	0.95	1.29	0.63	1.13
June	1.51	0.52	1.16	1.82	0.59	1.59	1.43	0.55	1.26
July	1.98	0.65	1.62	2.04	0.66	1.66	1.76	0.66	1.57
Aug.	1.81	0.64	1.61	1.68	0.64	1.38	1.56	0.68	1.13
Sep.	1.51	0.65	1.29	1.45	0.65	1.3	1.43	0.64	1.39
Oct.	1.22	0.62	0.99	1.22	0.64	1.15	1.28	0.62	1.26
Nov.	1.27	0.59	0.83	1.28	0.66	1.18	1.29	0.65	1.21
Dec.	1.44	0.75	0.78	1.57	0.73	1.47	1.43	0.74	1.23
Avg.	**1.4**	**0.6**	**1.1**	**1.4**	**0.6**	**1.3**	**1.4**	**0.7**	**1.3**

Table (3) Measured Salinity Upstream and Downstream Abd El Hay Weir

Month	Salinity at Abd El Hady (ppm)	
	Upstream	**Downstream**
Jan.	832	1690
Feb.	730	1069
Mar.	685	1370
April	896	1280
May	486	973
June	557	1248
July	678	1702
Aug.	742	1581
Sep.	678	1254
Oct.	627	1043
Nov.	621	1011
Dec.	819	800

WATER QUALITY ANALYSIS

In cooperation with the Central Laboratory of National Water Research Centre the physical properties of water; (which includes Salinity, Electric conductivity (Ec), total dissolved salt (TDS), PH, Turbidity, Temperature and dissolved Oxygen (DO)) have been analyzed at 43 locations. Most of these measurements were carried out at the vicinity of the mixing zone at the confluence of escape of El Bats drain and Bahr Wahba just upstream Abd El-Hady Weir. the physical properties of water from the intake till 30 m upstream the escape of El Bats drain can be considered fresh water where the salinity increases and the dissolved Oxygen was above 5 mg/l which is the standard measures according to the environment Law No. 48 year 1982.

HYDRODYNAMIC MODEL

The hydrodynamic model is made with the SOBEK software package. The Channel Flow module is used to simulate the 1D-hydrodynamic flow in the canal. Therefore a schematisation of the canal is made, which includes all the weirs, regulators, and El-Bats pumping station. The Real-Time Control module is used to simulate the way of managing the control structures. This module is not used for the hydraulic design, but will be used to test and design the control of the canal

The objectives to use a hydrodynamic model of Bahr Wahba canal are to:

- Test the hydraulic performance of the canal together with the hydraulic structures under the design conditions.
- Test the behavior of the system under extreme conditions (as well maximum as minimum discharges).
- Check the effect of different discharge ratios, between fresh water (through the canal intake) and Saline water (through El-Bats pumping station), on canal performance.

1. Model Calibration

In order to be sure that the model is really simulating the prototype, the model is calibrated by using the measured field data. The implemented data for calibration are as follows:

a- The geometric properties of the 61 measured cross-sections and the measured water levels along the canal for geometric simulation.

b- The measured discharge downstream intake regulator is used as upstream boundary condition (USBC).

c- The measured water level upstream Om El-Atl Weir is used as downstream boundary condition (DSBC).

d- The measured characteristics of hydraulic structures located at km, and the measured water levels upstream and downstream them.

e- The inflow discharge from El-Bats drain to the canal and outflow discharge through the offtakes structures are used as an internal boundary conditions (IBC).

Table (4) illustrates the collected data which have been involved in the calibration phase.

Table (4) Model Calibration. Used Parameters

Location (Km)	Name	Discharge (m^3/s)	Water Levels + MSL
0.0	D. S wahba Intake	17.97	23.08
17.450	U.S Railway Barrage	11.30	22.18
17.500	D.S Railway Barrage	13.25	19.58
19.870	U.S Hababa Barrage	10.12	19.48
20.200	D.S Railway Barrage	7.75	16.40
25.980	U.S Nagib Weir	9.62	16.10
26.000	D.S Nagib Weir	9.46	14.58
40.000	U.S El Bats Escape	0.83	13.72
46.850	D.S El Bats Escape	3.27	13.72
52.130	U.S Om El Atl	2.30	13.20

The formula used for roughness simulation is the formula of Chezy according to Manning which is : $C = \frac{1}{n} R^{\frac{1}{6}}$

where : $C = 18 \log (12R/K_s)$
n = Manning's coefficient
K_s = Equivalent sand height in (m)

Using this formula instead of selecting constant Chezy values allows the model to change the Chezy roughness coefficient C for each cross section with water level variations.

Figure (4) and Tables (5, 6, 7) show the results of the calibration phase.
The calibration results are as follows :

Table (5) shows the measured and predicted discharges along the canal;
Table (6) shows the measured and predicted velocities at the measured cross sections;
Table (7) shows the measured and predicted water levels.

2. Model Operation

Because the central water quality control for maximum allowable salinity concentration of irrigation water scheme is going to be used, the capacity of Bahr Wahr from is head regulator to Abd El-Hady weir is checked for a maximum discharge of 19.20 m3/s. The results of this test are shown in Figure (5).

In order to get the water levels at the offtakes the model is running for the following conditions:

Condition 1 : Intake regulator discharge 8:39 m^3/s and for El-Bats 0.26 m^3/s.
Condition 2 : Intake regulator discharge 13:89 m^3/s and for El-Bats 2.75 m^3/s.
Condition 3 : Intake regulator discharge 16:92 m^3/s and for El-Bats 4.66 m^3/s.

The results of these tests are shown in Figure (6) and given in Table (8).

Table (5) Measured and Predicted Discharges in the Calibration Phase

C.S. No.	Location (Km)	Discharge (m^3/s)	Discharge (m^3/s)
1	0	17.97	17.97
2	17.45	11.30	11.30
3	17.5	13.25	13.25
4	19.87	10.12	10.12
5	20.2	7.75	7.75
6	25.98	9.62	9.62
7	26	9.46	9.46
8	40	0.83	0.83
9	46.85	3.27	3.27
10	52.13	2.30	2.3

Table (6) Model Calibration, Measured & Predicted Average Velocities

C.S. No.	Location (Km)	Measured Velocity (m/s)	Model Output (m/s)
1	0	0.26	0.24
2	17.45	0.49	0.48
3	17.5	0.7	0.7
4	19.87	0.62	0.59
5	20.2	0.29	0.28
6	25.98	0.33	0.33
7	26	0.41	0.4
8	40	0.11	0.09
9	46.85	0.24	0.24
10	52.13	0.24	0.24

Table (7) Measured and Predicted Water Levels in the Calibration Phase

C.S. No.	Location (Km)	Water Levels (Measured) + MSL	Water Levels (Predicted) + MSL
1	0	23.08	23.09
2	17.45	22.18	22.15
3	17.50	19.58	19.58
4	19.87	19.48	19.44
5	20.20	16.4	16.4
6	25.98	16.1	16.08
7	26.00	14.58	14.6
8	40.00	13.72	13.72
9	46.85	13.22	13.22
10	52.13	13.2	13.20

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Table (8) Water Levels at Entrance of Main Offtakes

No.	Location (Km)	Name	Water Level		
			Condition 1	Condition 2	Condition 3
1	9.978	Seela Barrage	22.42	22.62	22.82
2	17.479	Bahr Losato	21.44	21.68	22.21
3	19.71	Aslan Canal	19	19.31	19.64
4	22.687	El-Hedoda Canal El-R	5.78	16.35	16.67
5	25.977	El-Robeat	5.56	16.24	16.6
6	31.615	Bahr El-Hogmn	4.05	14.57	14.74
7	34.665	Ganabia Bahr Wahba No. 1	3.89	14.45	14.62
8	39.545	Ganabia Bahr Wahba No. 2	13.64	14.28	14.43
9	46.833	Bahr Anas	13	13.35	13.59
10	49.671	Bahr Green	12.71	12.97	13.21

By using SOBEK model, we calculate the required fresh water in Bahr Wahba canal in order to minimize the salinity in the vicinity of mixing zone to be within the allowable limits. By knowing the available fresh water in Bahr Wahba canal we calculate the additional required fresh water. Table (9) shows the monthly additional fresh water required for Bahr Wahba canal and the total volume per year to maintain the salinity within the allowable limits.

Table (9) Monthly of Rate of Addition Required Fresh Water for Bahr Wahba canal

Month	**Available** M. m^3	**Required** M. m^3	**Additional** M. m^3
Jan.	25.13	26.13	1.00
Feb.	30.69	33.29	2.60
Mar.	38.24	39.94	1.70
April	36.13	38.20	2.07
May	39.80	40.09	0.29
June	43.02	45.75	2.73
July	43.18	49.03	5.85
Aug.	42.95	48.42	5.48
Sep.	36.79	39.53	2.75
Oct.	35.39	37.22	1.82
Nov.	34.45	35.82	1.37
Dec.	32.27	34.94	2.67
Sum.	**438.04**	**468.35**	**30.32**

OPERATIONAL MANAGEMENT SYSTEM Error! Bookmark not defined.

The function of the Operational Management System (OMS) of Bahr Wahba canal is to deliver a pre-defined amount of water to the various offtakes that are supplying 45,225 feddans of land. This water should be of good quality i.e. of a salinity concentration lower than a pre-defined maximum. The OMS must execute its tasks in a robust, economic, transparent and flexible way.

In this part of the project, several meetings were held with the staff of Irrigation Department at Faioum. The Operational Management System of Bahr Wahba is proposed to have the following components:

- A Supervisory Control And Data Acquisition system located in the Central Operation Room of the irrigation scheme, containing control rules, system monitoring visualization, alarm visualization, data logging and automatic report generation.

- Control of the head regulator and the supply structure from El-Bats drain to the main canal.
- Measurement stations sampling relevant water levels and water quality variables for Real Time Control operations and monitoring of the whole system.

  Monitoring component with communication lines and online visualization of the whole system.
- Alarm component.

Note that control is used in a general way irrespective of the fact whether this control is executed automatically or manually.

In Sections 1, 2 and 3 the components concerning the Real Time Control are discussed. The components that complete the whole OMS are addressed in paragraph 4.4.

1. Specification of Real Time Control objectives within the OMS

The Real Time Control (RTC) system within the Operational Management System comprises those components that are responsible for the continuous control of the objectives of the OMS. A set of alternative RTC configurations are selected and tested. The RTC configuration is built to satisfy the following objectives of the system:

- The system should use as much as possible drainage water and only use the fresh water of Bahr Youssef to mix to attain the required canal discharge within a maximum allowable salinity concentration.
- The salinity concentration in the main canal should not exceed the maximum allowable salinity concentration of 1,000 ppm. If this situation occurs an alarm is generated and the RTC system is automatically turned off.
- The offtakes have a 24 hour continuous flow. This means that it does not anticipate a varying day and night offtake pattern, though the RTC system will be set-up in a flexible way to accommodate for future adjustments in this objective.

2. Water Quantity Control

When considering the water quantity system, the inputs are the flow through the head regulator and the flow of El-Bats pumping station, while the outputs are the offtakes along Bahr Wahba. The flows can be controlled through Bahr Wahba by having the structures in the main canal maintain a certain water level. The Weir Structures in the main canal execute this task, while the regulators are fully opened and not taking part in the RTC system. The choice of the location where the water levels should be maintained has still to be made as part of the design of the RTC system. The possibilities are:

The water quality variable that is taken into account in the RTC system is the salinity concentration of the irrigation water in particles per million (ppm).

The water quality system has its inputs the salinity concentration of the flow through the head regulator and the flow through El-Bats pumping station. Its governing output is the salinity concentration downstream of the confluence of the flow from the pump station. Further downstream, no changes in the salinity concentration are to be expected. This output salinity concentration should not exceed a certain maximum value. This maximum value can vary in time. The value of this maximum concentration in time could vary as a function of the actual crops in the fields as well as the stage of their growth.

CONCLUSION

The central water quality control for maximum allowable salinity concentration (1000 ppm) of irrigation water is a recommended configuration for controlling Bahr Wahba.

- The total amount of water, required to keep the maximum salinity downstream Abd El-Hady weir within the allowable value of 1000 ppm, is 30.32 Million m^3 per year.
- The monthly rate of additional required water at the intake of Bahr Wahba is shown in Table (9).
- The capacity of Bahr Wahba is enough to safely carry the maximum discharge from Bahr Yousef, which is 19.20 m^3/s.

RECOMMENDATIONS

A telemetry and voice communication systems, are recommended for optimal operation and best water management.

- The project of supplying El-Giza Canal from El-Mouhit drain should be completed in order to increase the water budget for Faiom Directorate. This water is required to cover the addition fresh water for Bahr Wahba.
- The water level of lake Qaron should be monitored continuously because of the increase sin the discharge of El-Bats drain. It is recommended to have a remote station for water level measurement in the Lahe and to send its results to the central station.

ACKNOWLEDGMENTS

This paper was derived from a published technical report performed in the Hydraulics Research Institute (HRI) of the National Water Research Center (NWRC), Egypt. The report was published in Jan 2001. The writers would like to express their appreciation to Prof. Dr. M. Gaweesh (Director of HRI) and Eng. I. El-Desouki (Deputy Director), for their support and assistance in formulating this paper and their valuable comments, which led to improvements in the final manuscript.

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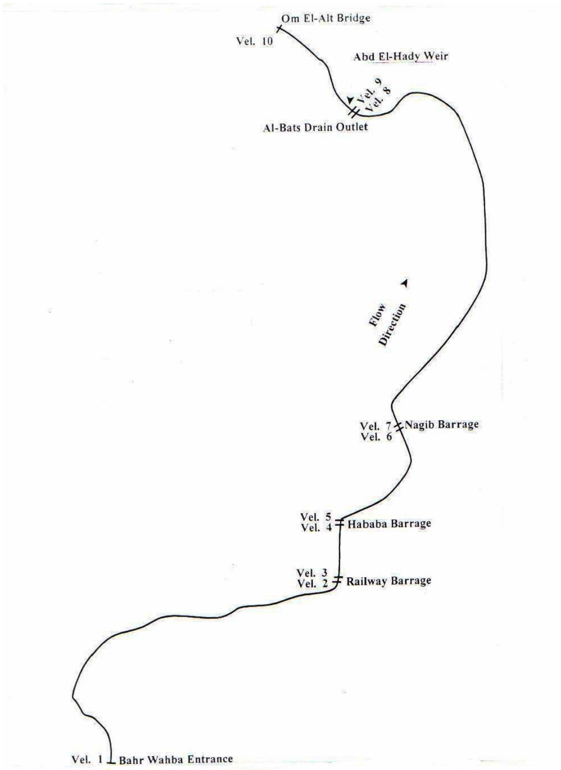

Fig. (1) General Layout of the Surveyed Area and Velocities Measurements Locations

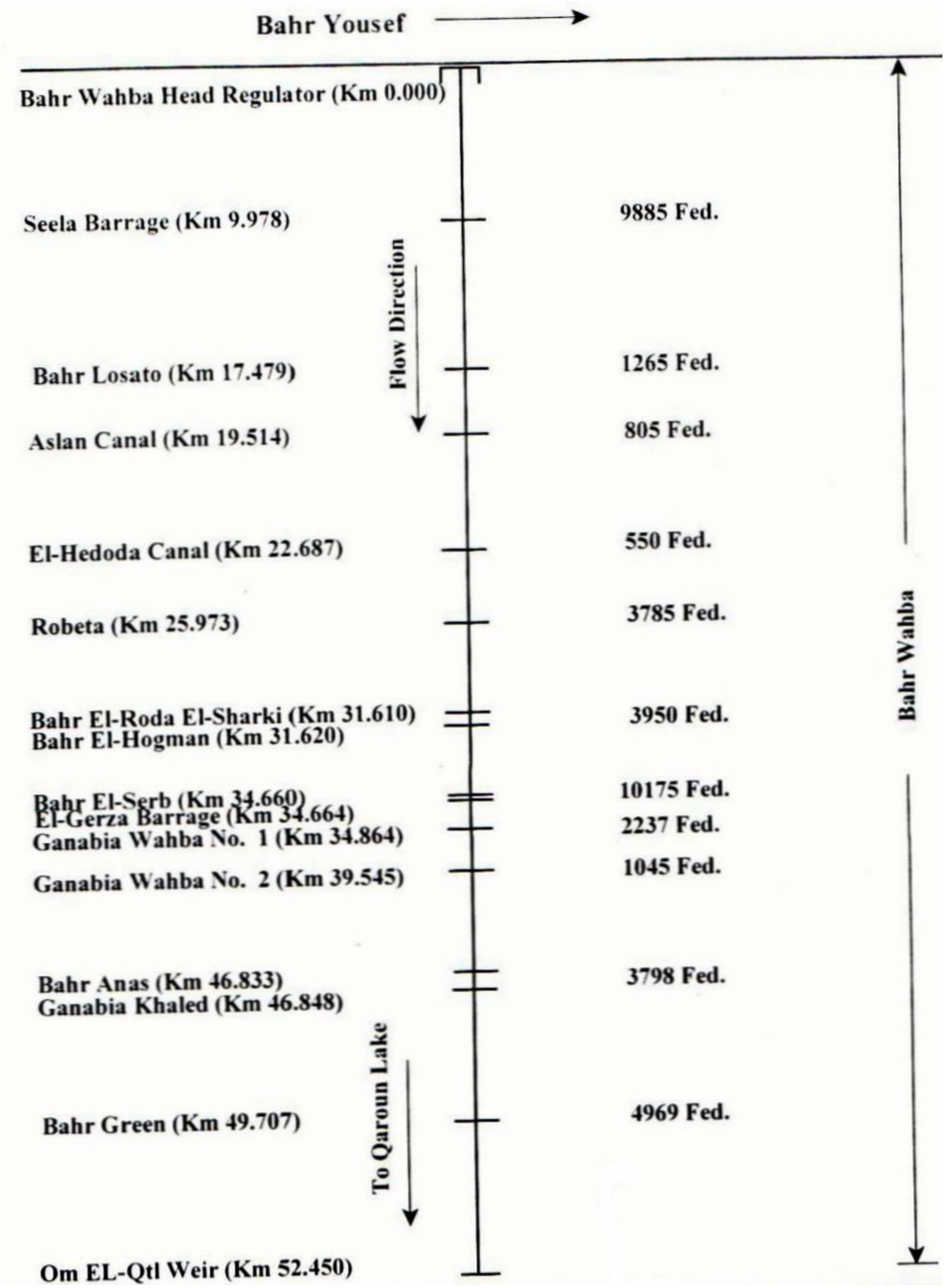

Fig. (2) Location of The Intake Structures along Bahr Wahba Canal

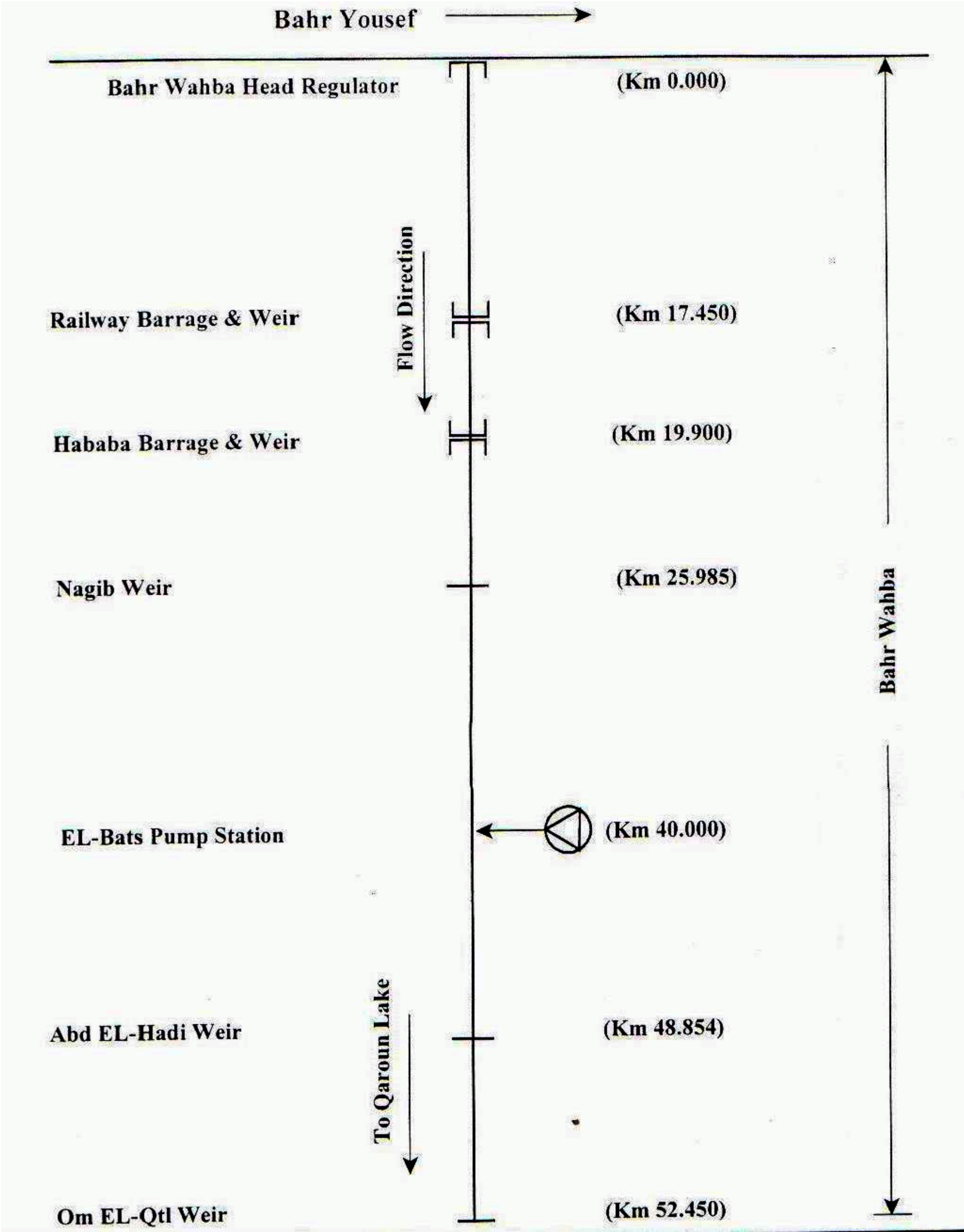

Fig. (3) Schematization Layout of the Study Area

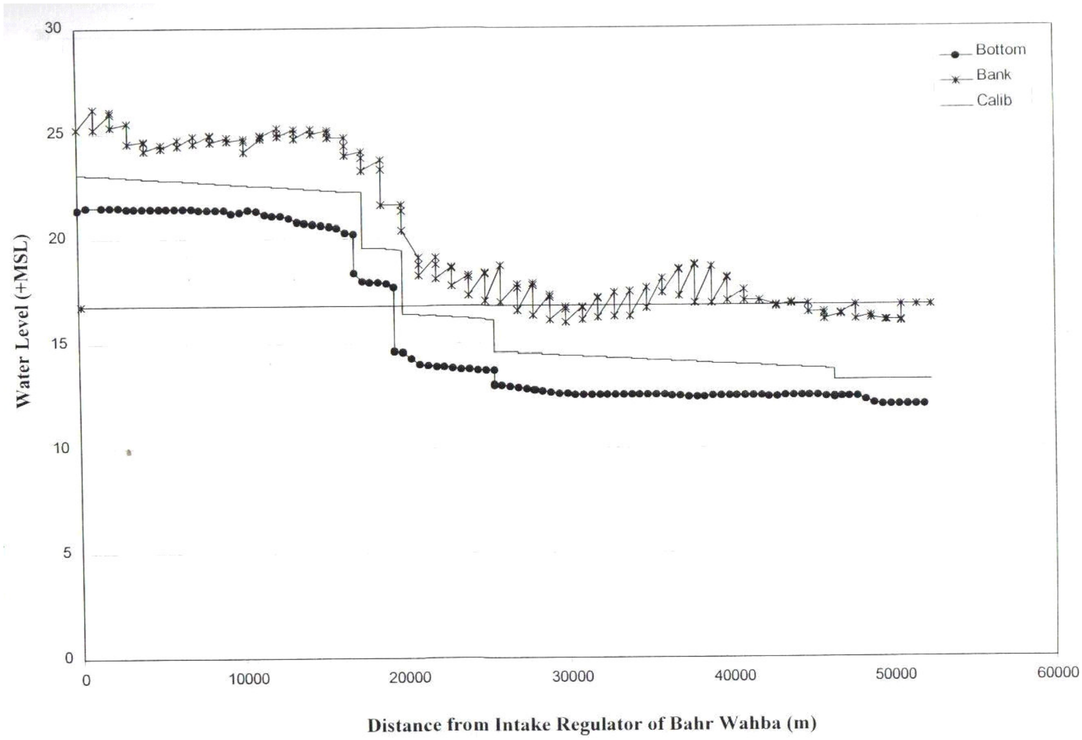

Fig. (4) Water Surface Profile along Bahr Wahba Canal (Calibration)

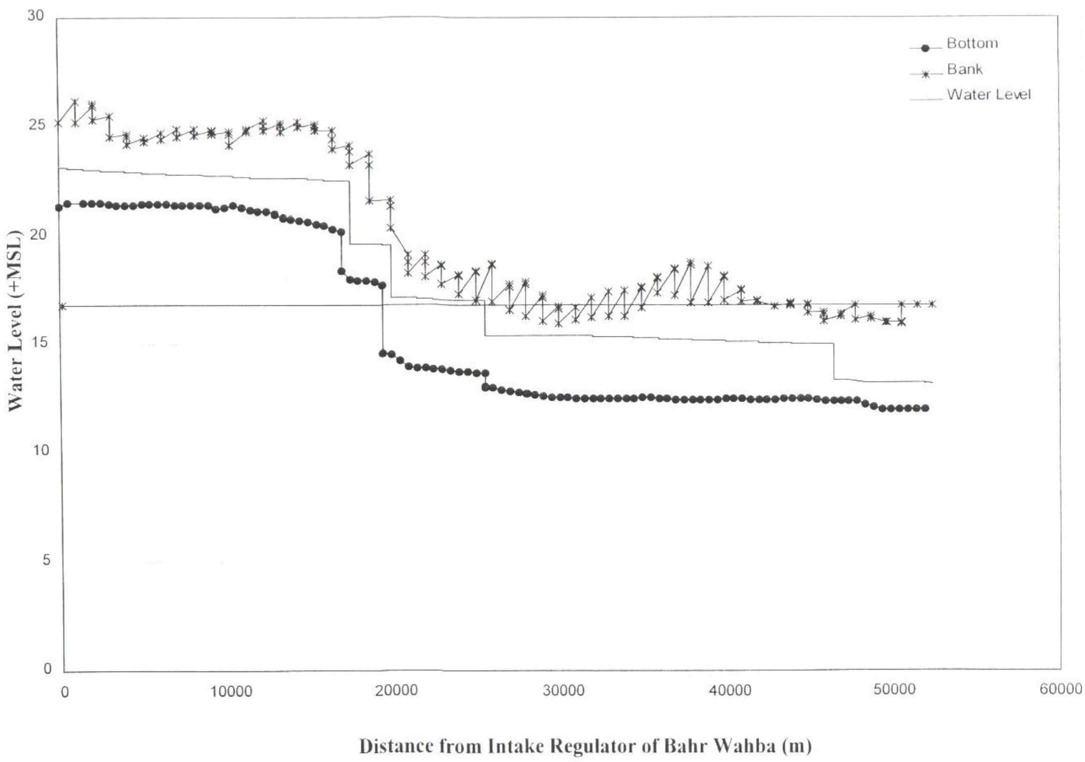

Fig. (5) Water Surface Profile along Bahr Wahba Canal (Maximum)

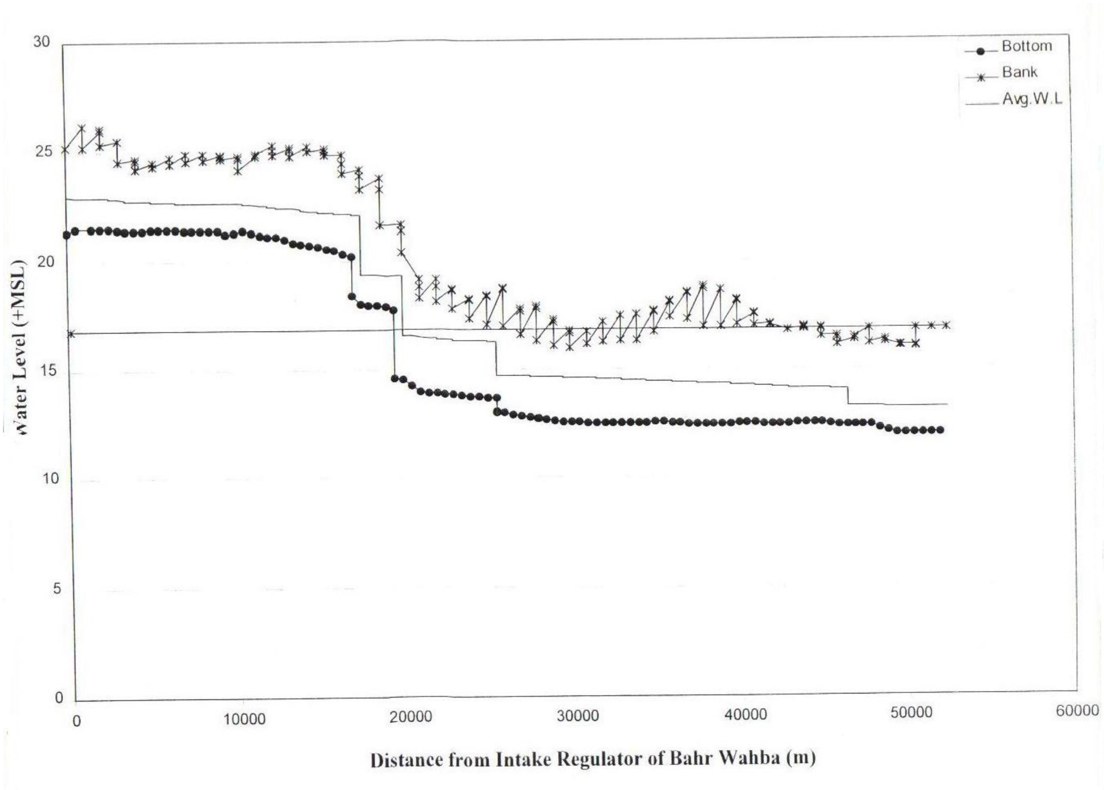

Fig. (6) Water Surface Profile along Bahr Wahba Canal (Conditions 1, 2, 3)