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DATA COLLECTION TECHNIQUES IN OPEN CHANNEL IRRIGATION SYSTEM (THE EGYPTIAN CASE STUDY)

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الملخص
تنتشر نظم الرى المعتمدة على شبكة القنوات المفتوحة ومنشآت التحكم مثل القناطر فى عدد من البلدان مثل مصر والهند والولايات المتحدة وغيرها. يعتبر حجر الزاوية فى كفاءة هذه النظم هى حالة وأداء قناطر التحكم سواء فى المدخل أو على طول القنوات. تتميز هذه النظم بزيادة العمر الافتراضى لها وبإمكانية بقائها لمدة طويلة بنفس الأداء طالما تتم عمليات التقييم وإعادة التأهيل للمنشآت بشكل دائم. العامل الأساسى المؤثر فى عمليات التقييم وإعادة التأهيل هو وجود بيانات كاملة وموثوقة عن منشآت التحكم. لهذا تعتبر عملية تجميع البيانات هى العملية الأهم فى إدارة هذه المنشآت. هذا البحث يقدم عدد من التقنيات التى يمكن استخدامها لتجميع بيانات نظم الرى مثل الرفع المساحى الأرضى والتصوير الجوى والتصوير الفيلمى تحت المياه وغيرها ومدى ملاءمة كل من هذه التقنيات لنوعية البيانات المطلوب تجميعها مع تطبيقها على حالات تجميع بيانات حقيقية لشبكة الرى المصرية.

ABSTRACT
Systems of irrigation that involve open channels network and control structures like regulators exist in many countries such as Egypt, India, USA and others. The corner stone of the efficiency of these systems is the performance of head and partial regulators. A very important advantage of these systems is that they live long with the same good performance as long as the evaluation and rehabilitation processes are conducted periodically. The main effective factor in evaluation and rehabilitation processes is the existence of complete and trusty data about the control structures. That is why the data collection process is considered the most important step in management of these structures. This paper presents some of the techniques to be used in data collection of irrigation systems such as land surveying, aerial photogrammetry, under-water video filming and the like. The appropriate technique for every type of data collected is introduced together with applications on real data collection cases in the Egyptian irrigation network.

KEY WORDS: Irrigation network, System evaluation and rehabilitation, Data collection techniques.

1. INTRODUCTION AND LITERATURE REVIEW
Egypt is an arid country extending over a million square kilometers with practically a sole and limited water resource coming from the Nile River that is being shared among other Nile basin countries. As a result, its agriculture sector depends mainly on the Nile water for irrigation. The control of the Egyptian water resources and irrigation system depends mainly on a group of consecutive Barrages and Regulators of the Egyptian Water System (BREWS). The BREWS should function efficiently to save water and optimize flow discharge. Most of the BREWS are rather old; built in the late 19th and early 20th century. Throughout their extended lifetime, BREWS have been affected by weathering, changes in loading conditions, creep, and other wear and tear effects that deteriorated their functionality, safety and stability.

The Government of Egypt (GoE) has been addressing the issue of evaluating the safety and efficiency of BREWS. The evaluation process aimed at improving the ability of decision making in the rehabilitation/replacement of any dysfunctional barrage or regulator of the BREWS. This will improve the management of water resources in the country up to the planning horizon of 2050. Due to the large number and high importance of BREWS, GoE issued the project of "Master Plan for the major Hydraulic Structures (MPHS)" to improve the knowledge and regain good functioning of BREWS that control water resources and the irrigation sub-sector of the country (www.africanwaterfacility.org).

Available in the literature, one may find many published research papers in the field of management, evaluation, and rehabilitation of hydraulic systems and hydraulic structures. In **2009**, **Mosley** and **Fleming** conducted field study to monitor the reductions in water use following rehabilitation of a flood-irrigated area on the Murray River in South-East Australia. They installed monitoring stations in ten irrigation water off-takes of the selected study areas and installed two ditch drains to collect saline groundwater and pump it to the river. They reported that water use per hectare in the fully rehabilitated areas is only one third that in other areas for the same crop yields. In **2013**, **Mishra et al**. evaluated the performance indicators of a rehabilitated minor irrigation project in Odisha state, India. The goal of rehabilitation was to augment and secure water resource for the project prior to Irrigation Management Transfer (IMT). The rehabilitation of the system involved engineering measures; repair of head regulator and conduct soil cut and fill to regain the design sectional dimensions of the canal system. It also included administrative measures such as formation of Water User Association (WUA); perform capacity building steps for WUA, and handing over the project to WUA.

A study for the effects of good management on the irrigation system was established in **2014** by **Suhardiman** and **Giordano**. They examined the varied actors and agendas within irrigation bureaucracies. The aim of the study was to evaluate the success in employment of hydraulics to give good service to farmers. In **2016 Garcia et al**. conducted field study to evaluate the visibility of rehabilitation from the economic point of view. The study comprised detailed assessment of costs in carrying out different measures required in the management plan Yarqon River, west bank, Palestine. Other research works may be found in **Fouial et al**. **2017** who studied the management plan and optimal operation of pressurized irrigation systems, **De Vincenzo et al. 2017**, who introduced an Economic Environmental Defense (EED) method for sustainable management of reservoirs, and **Almeida et al. 2018** who stressed on the need of sustainability system to assist and monitor the construction process. This study stressed the required data and suitable techniques for data collection in conducting Master Plan (MP) for BREWS. It is hoped to give a new insight to help researchers and irrigation engineers.

2. PROBLEM STATEMENT AND CASE STUDY

BREWS on the Nile and the Nile Delta (Figure 1) are at different stages of degradation. The main problems include hydraulic inefficiency resulting from leaks and dysfunctional gate operation. The BREWS also suffer instability resulting from the erosion of foundations, differential settlement caused by high traffic loads, deterioration of construction materials due to age and changes in soil bearing capacities over time.

The inefficiency of BREWS adds to water and food security situations and to the risk of losing lives and property in case of failure. The old and fragile structures are prone to

failure in the event of earthquakes. Egypt has a high level of earthquake activity with six destructive earthquakes in the last fifty years; Alexandria earthquake of 1955, Aswan earthquake of 1981 and Dahshour earthquake of 1992 (www.africanwaterfacility.org).
As mentioned before, GoE issued the project of MPHS. 140 hydraulic structures were considered; 6 Main Nile barrages, 16 head regulators at the off-takes of canals from the Nile, 31 intermediate regulators within Major canals, and 87 smaller regulators located within irrigation canals. The first step of successful MPHS is data collection of these 140 structures.

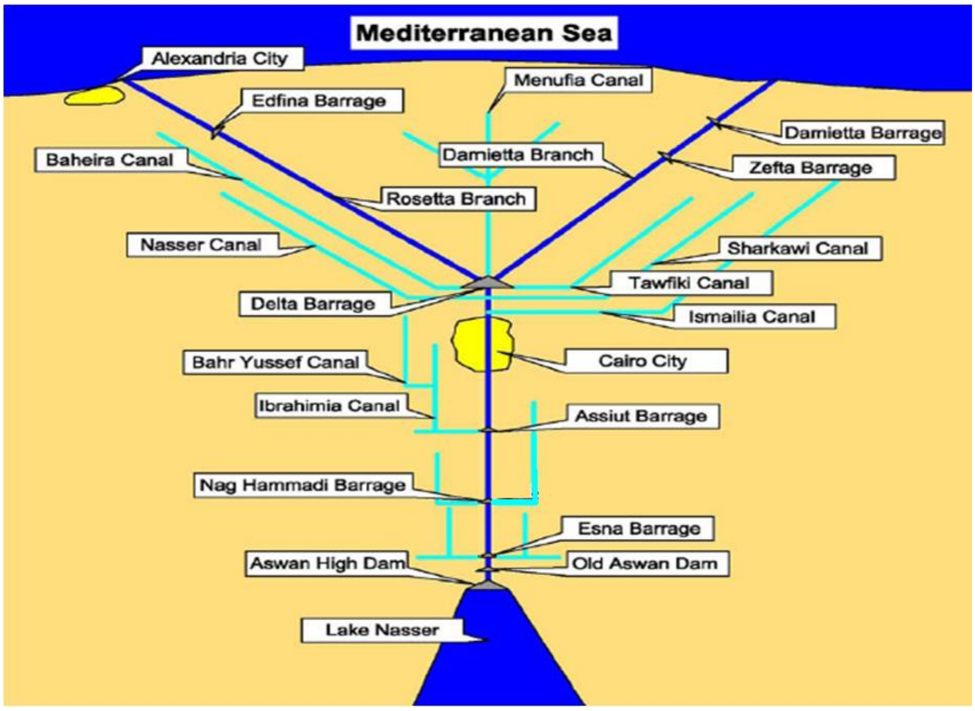


Figure (1): Irrigation water distribution system controlled by BREWS.

3. TYPES OF DATA AND TECHNIQUES

The process of collecting complete and trusty data is the most important step in MPHS. Collecting the required data about each one of the 140 structures is a tedious task and should be carried out with ultimate accuracy. Each type of data collected has its own methodology and special equipment. The 140 structures are clustered in 75 locations in the Nile Valley and Nile Delta. There are different types of data to be collected for each structure. Data is collected using the following techniques:

- *Visual inspection* of the BREWS and the collection of physical data related to the geometry, the structural state and the hydraulic performance of each BREWS.
- Carrying out *bathymetric and topographic survey* for modeling the hydraulic performance and the impacts of floods of varying intensities in structural failures.
- Undertaking detailed *site investigations* for up to 100 structures prioritized according to their economic, socio-economic, and environmental importance.
- *Underwater inspection* of up to 50 suspected structures to investigate the structural integrity of the submerged portions. This task involved the dewatering of one vent for each of 20 structures and drill boreholes to enable the inspection of the substructure.
- Design of a *Geographic Information System (GIS)* database to handle geographic, structural, geometric, environmental and socio-economic data and aerial photos and videos.

4. SELECTION OF DATA COLLECTION TECHNIQUES

The technique selected for data collection depends on the type of data. In the coming section, data collection techniques used in this study for every type of data are presented.

4.1 Visual Inspection: A situ visit was done, producing a site visit report including:

- Technical data short list included structure; name, construction date, distance from stream start point, name of canal, site altitude, number of vents, vent width, pier length, lock chamber details (if any), etc.
- Comments from personnel about the structure problems, the latest maintenance, etc.
- Photos of the structure and its location marked on satellite imagery.

4.2 Surveying: Topographic and bathymetric surveys were conducted.

- Topographic surveying determined distances, elevations, areas, etc. for topographic mapping.
- Bathymetric surveying focused on scour and river bed elevations:
    - An echo-sounder (sonar) mounted beneath the side of a boat sent a beam that was reflected by the river bed then transformed to data on the bathymetric map.
    - A mesh of beams was formed for an accurate output drawing of the river bed.
    - A zodiac (3m long and 1.5m wide) with motor was used.
    - If no bench mark was found, leveling was set with respect to a local static point.
    - The process was conducted using the method of sections (25 m apart) ended after 5 m in natural land in both sides of the bank.

4.3 Detailed Site Investigations: to get an inception report that involved three parts (a to c):

- Included inspection method, general description, hydraulic data, structural data, mechanical and electrical data, inspection results, recommendation of the inspection committee and priority of work required in the structure based on previous experience.
- Included photographs and drawings of the structure.
- Included the inspection form of the site visit.

4.4 Dewatering and Underwater Inspection: A specialized team was hired for the job with specialized equipment. The technique comprised the following:

- Cleaning the floor from silts and deposits using air lift.
- A monitor connected to the underwater camera enabled view of the inspected elements.
- Divers followed the instructions from the technical staff to locate any irregularity, crack or damage on the submerged parts.
- Underwater photography to concrete floor in a zigzag manner, wall to wall to investigate walls, groves, gate, and underwater mechanical parts.
- Video filming covered all underwater parts.
- For dewatering, the cofferdams were placed in the maintenance grooves, water pumps evacuated water and photos and video filming of the dewatered vent were carried out.

5. FORMATION OF THE GIS MODEL

GIS was used to develop the required database and make it easy to analyze the collected data to fulfill the preset aims of the MPHS project. The following steps were conducted:

- Performing the initial conceptual design of the GIS database and installing the Decision Support System (DSS) computer package under the umbrella of GIS.
- Procurement of items needed for the conceptualized GIS database.
- Development of GIS database structure, ready for the entry of structured datasets.
- Data compilation, check missing data, and preparation of missing data priority list.
- Site visits for visual inspection and missing data collection following the priority list.
- Entry of all available and collected data.
- Testing GIS database, creating access levels for different users, and providing a concise technical documentation explaining the system with user and programmer manuals.

6. APPLICATION OF THE SELECTED TECHNIQUES

Application example is presented here as part of the data collected in the project of MPHS. Bahr Mowees main canal is a branch of Tawfiky diversion canal (Rayah) and its head regulator was constructed in 1888 (see Figure 1). The structure has 7 vents, each is 3 m wide. Bahr Mowees main canal irrigates 487000 fed. Non-functioning symmetrical lock with 8 m width is located parallel to the structure. Following hereafter are the data collected using the pre-mentioned techniques in Bahr Mowees Head Regulator (BMHR).

6.1 Site Visit Report: Site visit showed that the navigation lock is not operating due to the construction of an immovable bridge over it, the gates were fully opened, and maintenance was carried out in years 1994 and 2004. Table (1) shows the technical data, photo (1) shows BMHR from the downstream and photo (2) is a satellite image showing the location of BMHR.

Table (1): Technical Data short list of Bahr Mowees Head Regulator (BMHR)

Name	BMHR	Navigation Lock	Yes
Construction Date	1888	Symmetrical	Yes
Distance from stream start point (km)	35	Number of Vents	7
Canal	Tawfiky Rayah	Vent Width (m)	3
Irrigation Directorate	Delta Barrage	Pier Length (m)	9.88
Structure Type	Combined	Lock Chamber Length (m)	55
Latitude (UTM 36N, m)	30.4877	Lock Chamber Width (m)	8
Longitude (UTM 36N, m)	31.2161	Bridge Location	Inside

Photo (1): General view of BMHR from the D.S.

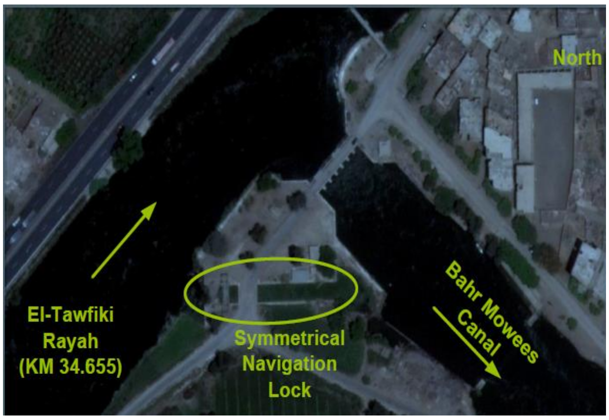


Photo (2): Satellite Image of BMHR

6.2 Surveying (Topographic and Bathymetric): Figures (2 a, b, c, d) give the drawings resulted from the topographic surveying. The bathymetric surveying was conducted using a boat equipped with marine computer loaded by professional navigation software. The computer was attached to a Wide Area Differential Global Positioning Systems (WADGPS) and a dual frequency Echo-sounder (50 to 200 hertz). The mesh was 5x5 m. Sound velocity of 1500 m/sec was set in the LOWRANCE X 59 DF processor. Water level variations were measured every one minute during the field survey using an electronic tide gauge. Examples of the water surface profiles and bed configurations are demonstrated in Figures (3) and (4).

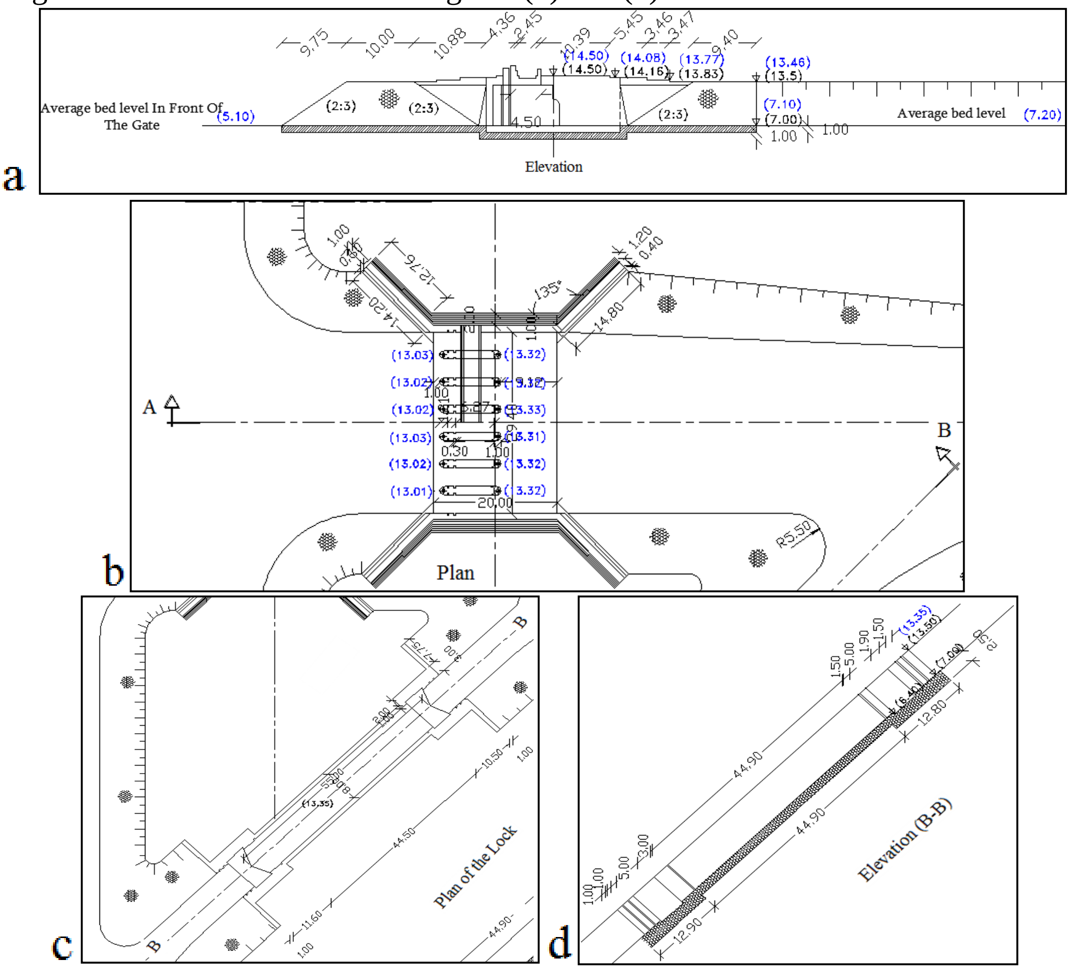


Figure (2 a, b, c, d): Plan and Elevation of BMHR and lock based on structure survey

6.3 Detailed Site Investigations: Examples of the outcome data collected included:

- *Population served*: 5,340,000 cap, Rate of increase is 2.7%, Area served is 4911km^2.
- *Cropping pattern*: Cotton, Wheat Rice, Corn, Beans, Sugar beet, and Vegetables.
- *Water Treatment Plants (WTP)*: 218 WTP with total discharge of 600,000 m^3/day.
- *Plain concrete core samples*: samples with 9 cm length were obtained.
- *Reinforced concrete samples*: No samples were taken to prevent jeopardizing the structures stability especially for a 130 years old structure.
- *Photos*: Photos (3 to 6) were targeting parts of the super-structure to help in analysis.

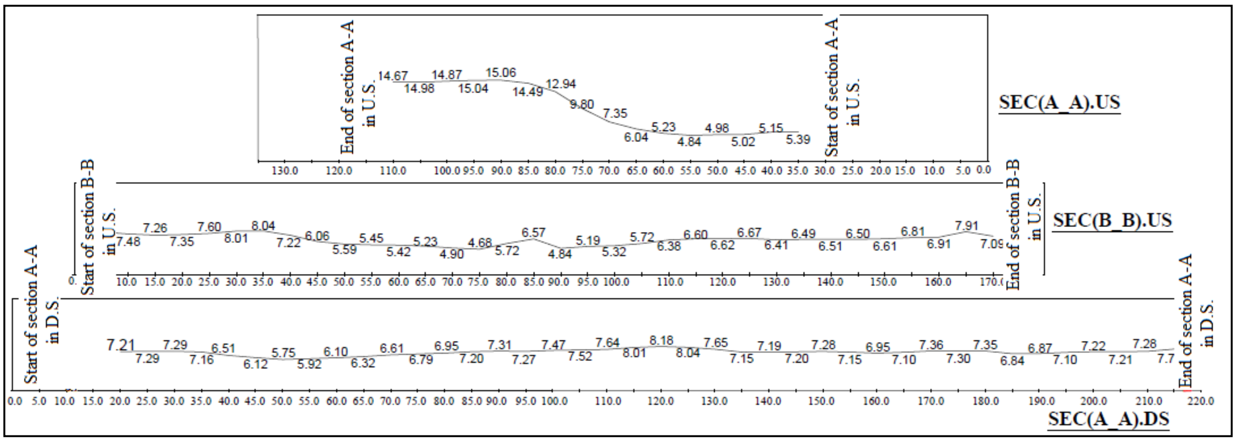


Figure (3): Examples bathymetric surveying output for longitudinal water surface profiles

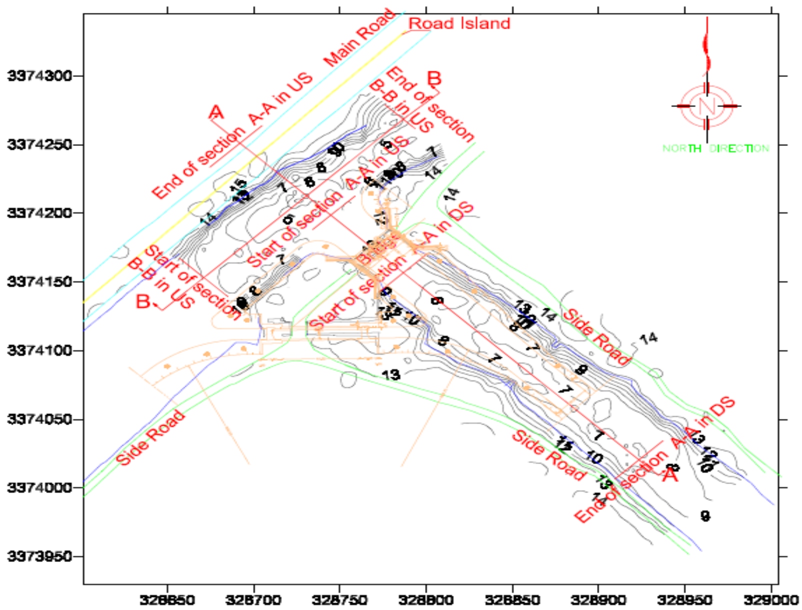


Figure (4): Outcome of bathymetric surveying general plan and bed contour map

Photo (3): General view of Regulator U.S.

Photo (4): Wing wall, D.S.

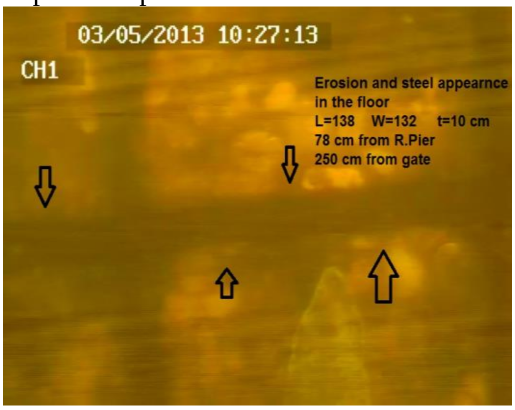
Photo (5): Gate lifting system

Photo (6): Regulator gates

<u>6.4 Dewatering and Underwater Inspection:</u> The most critical vent was determined from the underwater inspection and it was chosen for dewatering to collect the required soil samples for soil strength and structural stability analysis. The underwater reports gave the following data:

- The floor material is white stones with 8 m length and 3.2 m depth in the DS and 3 m length and 4.2 m depth in the US.
- There is a gap under the gate of about 20 cm.
- Erosion exists along the emergency gates.
- Pier number (1) DS: Gap 10 cm length, 6 cm width, 17 cm thickness, 3.15 m under Water Level (WL), and 1.25 m from gate.
- Pier number (2) DS: Gap 43 cm length, 35 cm width, 30 cm thickness, 3 m under WL, and 2 m from gate.
- Pier number (1) US: Gap 16 cm length, 18 cm width, 20 cm thickness, 3 m under WL, and 0 m from gate.
- Pier number (2) US: Gap 43 cm length, 35 cm width, 30 cm thickness, 3 m under WL, and 2 m from gate.
- The floor is clear in the US
- Erosion existed in the floor DS with length 14 to 138 cm, width 6 to 132 cm, and thickness 12 to 200 cm.
- Underwater photography output is tabulated hereafter in Photos (7 to 10).
- Photos (11 to 14) show details of dewatering.

Photos (7) and (8): Gaps in the piers



Photos (9) and (10): Floor Steel Erosion

Photo (11): Installing steel boxes cofferdams

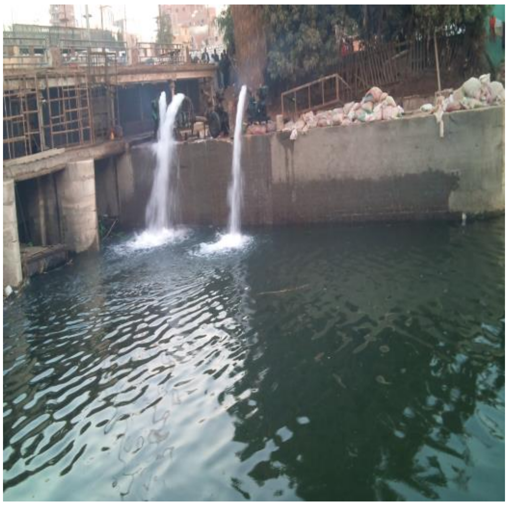


Photo (12): Pumping water out of the vent

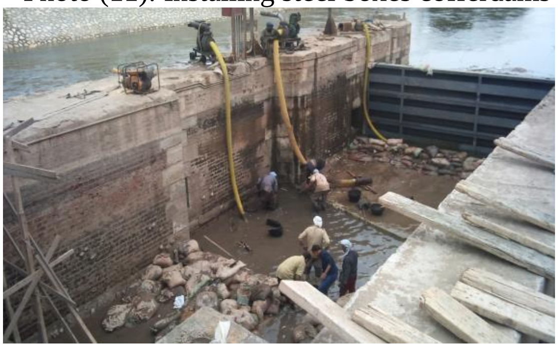


Photo (13): Cleaning the vent after water is pumped

Photo (14): Vent Repair

6.5 The GIS Model: Data was combined under the umbrella of GIS, and the DSS system in GIS is used. DSS enabled the prioritization of the different structures identified as requiring rehabilitation or replacement, in addition to availing the possibility of visualizing a variety of social-economic factors and analyzing their impact. In ArcGIS, all data files (such as Excel files) and drawing files (such as AutoCad files) were linked to be read through GIS.

6.6 Existent Conditions: Analysis of the collected data together with the inception report revealed that the BMHR existent conditions are as follows:

Structural Status:

- Roofs consist of brick arched vents for all 7 vents and the roof was elevated with reinforced concrete during last maintenance and the roof is in good condition.
- Piers and abutments consist of red bricks and copings are of Ashler stones and all are in good condition except for few spots that need restoration.
- Wing walls are of bricks and in good condition.

Hydraulic Performance:

- Marble gauge exists in wells U.S. and D.S.
- U.S. current water levels range between (12.37) and (11.40).
- D.S. current water levels range between (12.27) and (9.70).
- Current maximum discharge is 13.2×10^6 m^3/day.

Bridge Status:

- The bridge is of arched bricks overlain by plain concrete and max bridge load is 20 ton.
- U.S. and D.S. parapets are of bricks and Ashler stones and are in good condition.
- U.S. foot steel path is in good condition.
- Bridge floor needs some restoration.
- Pitching U.S. and D.S. is of stones and needs maintenance.

Electromechanical equipment and gates:

- 7 double hung vertical gates for regulator vents are mechanically operated.
- 2 movable diesel cranes are available in good condition for using the gates.
- The crane is electrically and manually operated.
- Light poles exist.

Instrumentation and control equipment

- U.S. emergency grooves need maintenance.
- The four emergency gates are in good condition.
- Emergency crane exists.
- No emergency pontoon exists.
- Stones blocks about 20 m^3 exist.

Other points of interest

- Workshops exist for turning, rolling, welding and carpentry.
- Warehouses were constructed in 2007.
- No residential units exist.

6.7 Decision: After compiling and analyzing the available data and the existing condition of the structure, it was found that the BMHR is in good condition and does not require replacement, but only to be subjected to the average maintenance requirements. The DSS showed that the structure rehabilitation is of average priority on a scale of low priority, average priority, and high priority.

7. SUMMARY AND CONCLUSIONS

Data collection process is considered the most important step in management of control structures. It is the first step upon which the performance of the structure may be evaluated and the measures to be taken in case of structure dysfunction may be planned. Many techniques of data collection were presented such as visual inspection, bathymetric and topographic survey, site investigations, underwater inspection (including photographing, video filming and dewatering), soil sampling through boreholes, and design GIS database. The techniques were successfully applied on different types of data to be collected in Bahr Mowees Head Regulator (BMHR) as part of the project of Master Plan for the major Hydraulic Structures (MPHS). Data analysis under the umbrella of GIS showed that BMHR needs rehabilitation and no replacement is required. The DSS showed that the structure rehabilitation is of average priority. This means that the rehabilitation of the BMHR is not as urgent as some other structures of the BREWS. Setting the priority of BMHR and other 140 structure is the corner stone in the yearly budget allocation process.

ABBREVIATION

BMHR	Bahr Mowees Head Regulator	MP	Master Plan
BREWS	Barrages and Regulators of the Egyptian Water System	MPHS	Master Plan for the major Hydraulic Structures
D.S.	Down Stream	U.S.	Upstream
DSS	Decision Support System	USA	United States of America
EED	Economic Environmental Defense	WADGPS	Wide Area Differential Global Positioning Systems
GIS	Geographic Information System	WL	Water Level
GoE	Government of Egypt	WTP	Water Treatment Plants
IMT	Irrigation Management Transfer	WUA	Water User Association

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