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An Approach for Data Analysis, Evaluation and Correction: A Case Study from Man-Made River Project in Libya

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***Abstract*—**The world's largest Pre-stressed Concrete Cylinder Pipe (PCCP) water supply project had a series of pipe failures which occurred between 1999 and 2001. This has led the Man-Made River Authority (MMRA), the authority in charge of the implementation and operation of the project, to setup a rehabilitation plan for the conveyance system while maintaining the uninterrupted flow of water to consumers. At the same time, MMRA recognized the need for a long term management tool that would facilitate repair and maintenance decisions and enable taking the appropriate preventive measures through continuous monitoring and estimation of the remaining life of each pipe. This management tool is known as the Pipe Risk Management System (PRMS) and now in operation at MMRA. Both the rehabilitation plan and the PRMS require the availability of complete and accurate pipe construction and manufacturing data

This paper describes a systematic approach of data collection, analysis, evaluation and correction for the construction and manufacturing data files of phase I pipes which are the platform for the PRMS database and any other related decision support system.

***Keywords*—**Asbuilt, History, IMD, MMRA, PDBMS & PRMS

I. Introduction

THE Man-Made River Project (MMRP) is a water supply project located in the North African state of Libya. It was constructed to extract and convey high quality ground water from deep aquifers in the Sahara Desert to the northern coastal strip where over 90% of the population lives. To date, three phases (I, II and III) of the project have been completed and currently under operation. They consist of 463,440 (3,847 Km) of mainly 4.0 meter diameter PCC pipes that convey 4 millions cubic meters of water per day from 674 production wells at Sarir, Tazerbo, East Jabal Hasouna and North East Jabal Hasouna to end reservoirs at costal strip (Essamin and Holley, 2006). The layout of these phases as well as the future phases is shown in Figure 1**.**

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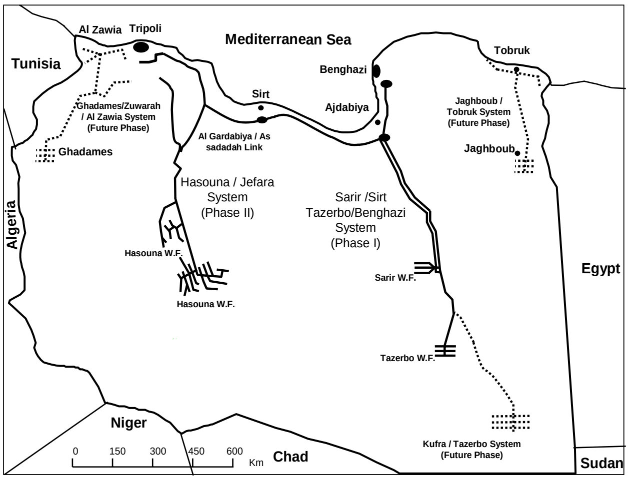

Fig. 1 Layout of MMRP phases [1]

II. Overview of the Case Study

In August 1999, MMRA encountered a first pipe failure in the Sarir-Sirt line of the Phase I conveyance. This first event was followed, a month later, by a second failure on the parallel Tazerbo-Benghazi line of the same phase. Between September 1999 and April 2001, three other failures occurred [2].

On-site investigations and studies carried out by MMRA experts concluded that the failures were caused by chloride-induced corrosion of the pre-stressing wires. The challenge that faced the authority was the assessment of the conveyance pipelines condition and determining the distressed pipes in order to setup a rehabilitation plan for the conveyance while maintaining the uninterrupted flow of water to consumers. This was particularly critical because the MMRP accounts for almost 100% of domestic water supply for the entire population (over one million) of the coastal region from Sirt to Benghazi [2].

To achieve these goals, a complete and reliable set of pipe data containing all construction and manufacturing data (Asbuilt and History files) for each pipe should be available in order to facilitate corrosion surveys, electromagnetic and acoustic monitoring inspection methods which were planned to be conducted to assess the condition of the conveyance.

The Asbuilt and History files together with the results of various inspection methods and soil tests will form the base of the PRMS.

The preliminary analysis and evaluation of the pipe data contained in both the Asbuilt and History files for Phase I conveyance system conducted by MMRA Information Management Division (IMD) resulted in detecting many errors in both files. More investigations have been carried out to determine the cause of these errors in an attempt to correct these problems with the objective of arriving at a complete and reliable set of data for each pipe.

The IMD communicated with Dong Ah Consortium (DAC), who was in charge of recording these data, with the objective of completing the missing data and clarifying several issues regarding the incorrect data. Because of DAC key persons originally involved in this work had left the project long time ago, the IMD continued to carry out the investigations and collection based on the experience of several senior engineers and extensive checks and reviews of the Asbuilt drawings, design charts and manual registers.

The approach of the analysis and results obtained as well as the development of a simple Pipe Database Management System are presented next

III. Methodology

A. Data Collection

Pipe Asbuilt and History data were originally obtained from construction and manufacturing archives at the different sites and entered using a main-frame computer operated by UNIX operating system. The IMD has initially faced many problems in converting such data to a PC format. These problems were mainly related to downloading programs and disk space availability. The required data (though incomplete) were finally obtained in Ms Access format. Table I shows the total number of fields and records for each file. These data files were then subjected to structure modifications and many kinds of analyses and corrections.

TABLE I
Total number of fields and records for Asbuilt and History files

File	Records	Fields	No. of Entries
Asbuilt	*248,828*	*41*	47.3 millions
History	236,314	157	

B. Structure of the Asbuilt and History Files

1. The Asbuilt file

The structure of this file has been slightly modified. Three (out of 41) fields were temporarily omitted and classified as secondary fields. New fields were added for validation purposes and better identification of pipe types.

2. The History file

The structure of this file has been slightly modified. 128 (out of 157) fields were temporarily omitted and classified as secondary fields. New fields were added for validation and statistical purposes.

C. Data Analysis and Correction

The analysis of the pipe data contained in both the Asbuilt and History files for the Phase I conveyance system resulted in detecting many errors in both files. Both analyses and corrections were done by using Ms Excel and Ms Access database tools. Many rounds of analyses using a systematic approach were carried out as more corrections are made after each round. Tables 2 to 6 show summary results obtained after each analysis.

1. Duplications

Both Asbuilt and History files were initially scanned for duplications. Based on the primary key (Pipe Production Line + Mark No.) as a combined index field to uniquely identify each pipe, 9,962 duplicates were found in the Asbuilt file (Both SS & TB), while 2,221 duplicates were found in History file. These were found to be rejected pipes (pipes with Mark No. = 0) which were then removed from the History file and saved into another file for record. These duplications were corrected. As more missing data have been found and added, further scans have been performed and consequently further duplications have been detected and corrected. This process continued until no more duplications were detected.

2. Missing entries

Missing entries (blanks and zeros) were initially detected in both files with about 31% in the Asbuilt file and 23% in the History file. The values of these entries were generated based on Quality Assurance (QA) records and the combinations of design tables and charts. The scanning and corrections processes continued until all data have been completed.

3. Incorrect entries (out-of-range entries)

Using the allowed values for each field obtained mainly from design tables and charts, out-of-range entries were initially detected for only two fields in the Asbuilt file and seven fields in the History file. These out-of-range entries were also corrected based on QA records and the combinations of design tables and charts. The scanning and corrections processes continued until all data have been corrected.

4. Incorrect entries (inconsistent entries)

Internally inconsistent entries were detected by adding temporary calculated fields (usually through design formulas) and comparing the values under these fields with their corresponding values in existing fields. These entries were detected within the Asbuilt file such as the values under the two fields (the generated and original) which should be equal. Similarly, inconsistent entries were detected within the History file using a design table that specify valid combinations of Soil Density, Earth Cover, Design Pressure, Pipe Wrap and Wire Diameter for the different pipe diameters and types.

This validation was made at a later stage after completing most of the missing data as summarized in tables 2 and 3. All these inconsistencies were corrected based on QA records and the combinations of design tables and charts.

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D.Linking the Two Files (Asbuilt and History)

The Asbuilt and History files should have a one to one correspondence based on the common composite field (Pipe Production Line + Mark No.) since each record in each file represents a unique pipe.

1. Matched records

There were initially 184,937 matched records in both files (of which 182,833 are unique) as depicted in figure 2.

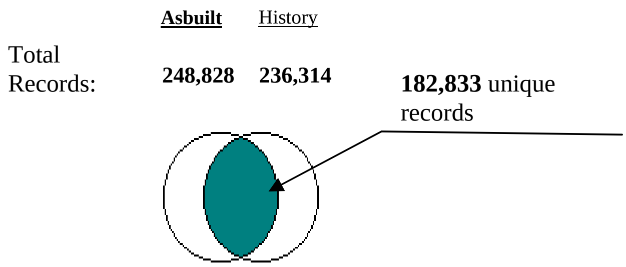

Fig. 2 Matched records in both Asbuilt & History files.

2. Records in Asbuilt not existing in History

There were initially 56,901 records in the Asbuilt file not existing in the History file (of which 54,175 are unique) as depicted in figure 3

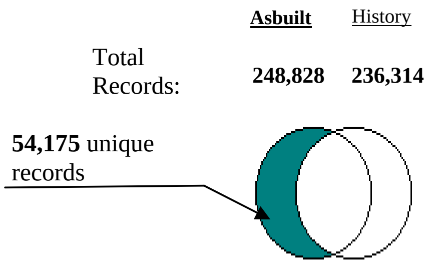

Fig. 3 Records in Asbuilt not existing in History

3. Records in History not existing in Asbuilt

There were initially 51,073 unique records in the History file not existing in the Asbuilt file as depicted in figure 4.

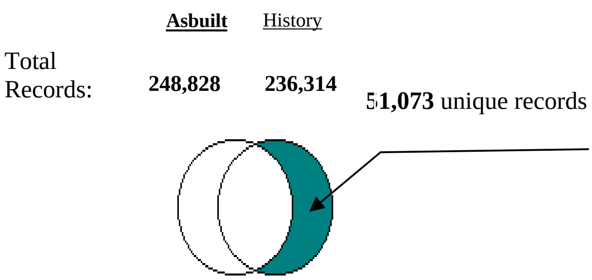

Fig. 4 Records in History not existing in Asbuilt

All unmatched records from both sides have then been eliminated as missing records were appended and all duplications were corrected or deleted.

E. Progress Summary

The progressive rounds of analysis are summarized in tables II to VI.

TABLE II
SUMMARY RESULTS OF THE ANALYSIS OF ASBUILT FILE

Asbuilt	1st Analysis	2nd Analysis	3rd Analysis	4th Analysis
Total Fields Added	3	5	9	9
Total # of Records	248,828	246,556	246,315	246,314
Total # of Duplication	9,962	5,485	96	0
Missing Entries	31%	15.9%	1.3%	0
Out-of-range Entries	867	851	701	0
Inconsistent Entries	-	-	244,225	0

TABLE III
SUMMARY RESULTS OF THE ANALYSIS OF HISTORY FILE

History	1st Analysis	2nd Analysis	3rd Analysis	4th Analysis
Total Fields Added	4	5	5	7
Total # of Records	236,314	236,878	247,097	246,314
Total # of Duplication	0	0	0	0
Missing Entries	23.4%	8.9%	1.8%	0
Out-of-range Entries	2,037	1,890	885	0
Inconsistent Entries	-	-	313	0

TABLE IV
SUMMARY RESULTS OF THE ANALYSIS OF MATCHED FILE

Matched Asbuilt with History	1st Analysis	2nd Analysis	3rd Analysis	4th Analysis
Total # of Records	184,937	235,270	246,311	246,314
Total # of Duplication	2,104	2,654	96	0

TABLE V
SUMMARY RESULTS OF THE ANALYSIS OF UNMATCHED ASBUILT RECORDS

Asbuilt not Existing in History	1st Analysis	2nd Analysis	3rd Analysis	4th Analysis
Total # of Records	56,901	11,286	5	0
Total # of Duplication	2,726	49	0	0

TABLE VI
SUMMARY RESULTS OF THE ANALYSIS OF UNMATCHED HISTORY RECORDS

History not Existing in Asbuilt	1st Analysis	2nd Analysis	3rd Analysis	4th Analysis
Total # of Records	51,073	4,262	834	0
Total # of Duplication	0	0	0	0

IV. A SIMPLE PIPE DATABASE MANAGEMENT SYSTEM

A. Introduction

After completing the analysis and corrections, the data were organized into 3 tables (Asbuilt, History and Distressed Pipes).

1. Distressed Pipes table

This table contains results of wire breaks details, for each pipe, detected by the Remote Field Eddy Current/Transformer Coupling (RFEC/TC) inspection technique. These details are: wire break position on the pipe, number of wire breaks at each position, inspection date and pipe identification (used to link with the Asbuilt and History tables).

The PDBMS was programmed in Ms Visual Basic (V. 6.0) running Ms Access (V. 97).

B. Main Modules

The system consists of:

1. Input/Output forms.
2. Pipe search.
3. Queries.
4. Statistics/Graphs.
5. Reports.
6. Database Utilities.

Appendix A shows the main functions/forms of the system.

V. CONCLUSIONS

1) A full set of data with a high degree of completeness and accuracy has finally been obtained. This was due to the use of rigorous error detection techniques implemented through iterative rounds of corrections and analyses. This work took about 2 years due to the massive amount of data and the accumulation of errors over long period (15 years). The results are summarized as follows:
   - Improvements were made to the structure, field organization and descriptions in both the Asbuilt and History files.
   - All duplications existing in the As-built file were eliminated.
   - The number of the missing entries (blanks & zeroes) in both files were eliminated.
   - All inconsistent and out-of-range entries in both files have been corrected.
   - A 100% match has been achieved between the two files due to the above mentioned corrections which led to the elimination of the unmatched records.
2) A simple pipe database management system, PDBMS, (using VB 6.0 programming language with Ms Access 97) has been developed. This DBMS drives the necessary input/output forms based on the full set of corrected and consolidated pipes data in addition to all distressed pipes data resulted from the RFEC/TC inspection technique.
3) Availability of complete and valid data integrated within a properly designed DBMS is a key element in effective planning and management decisions which, in addition to the benefit of cost and time savings, can serve as a base for any other decision support system that may be developed in other departments.

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Appendix A: Main functions/forms of the PDBMS for Phase I