Integrated water asset management system (IWAMS)

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Abstract As data proceeds through different levels of an organisation from its capture to its processing and refinement, it is reported as information relevant to a particular application. Data can be adversely influenced during this conversion process which can result in sub-optimal decisions being made. The collection and handling of information for a water authority must therefore be organised. Asset management systems generally consist of three major constituents: inventory, programmed action, and optimisation. The institutional capacity needs of water authorities in developing countries require greater emphasis on the first of these two constituents. A pragmatic and simple-to-use Integrated Water Asset Management System (IWAMS) has been developed comprising water meter, leakage control and incident management modules. A water audit and water balance module facilitates the determination of the levels of unaccounted for water, as well as the unit cost of leakage. Water mains rehabilitation priorities can be established through the representation of various data collected in the form of a common severity rating that aids decision making.

Keywords Asset; integrated; maintenance; management; operations; water

Introduction

In order for a water authority to function satisfactorily it requires information. This information is derived from data. Such data has to be collected, processed and interpreted to provide this information. A water authority is therefore dependent upon information to carry out its scientific, engineering and operational functions. The collection of any information must be carefully assessed as to its purpose, need, provision and cost. This assessment should be undertaken prior to devising a system for capturing data and deriving information.

The process with which data proceeds through different levels of an organisational structure involves its refinement as it progresses up through the structure. This process includes the areas of data capture, validation, processing and reporting.

Data capture includes referencing and collation prior to further processing. The validation of the data is of the utmost importance if the information to be derived from it is to be reliable. The use of range checks, limits, exception reporting and comparisons helps to identify any anomalies.

The processing path deriving information from data must be short and rapid. The amount of processing of data for reporting and archiving purposes varies with the particular requirement. Data can be reported and stored in its “raw” state, whilst in other areas summaries and derived statistics are preferred.

The provision of information for a water authority is something that has to be organised rather than just allowed to happen. Only if suitable data is captured can the information be useful. Its capture, validation, processing and reporting requires careful and considered planning if the information derived is to be useful and reliable (Mathews and Hilder, 1978).

Data acquisition cycle

The process of data acquisition through to the eventual application of the derived information can be described in the form of a cycle.
A data acquisition cycle can be used to illustrate the effect that a particular type and quality of data has on the design, planning, operation and management of a water supply and distribution system. This cycle of acquisition, evaluation, manipulation and application of data results in a response from the system which influences design, planning, operation, administrative and management policies which, in turn, can have an impact on the levels of for example, unaccounted for water. These policies will, therefore, eventually be revealed in the new data collected. The data acquisition cycle can also be used as an analogy with the communication process whereby various barriers distort or reduce the conversion of data to effective information (Johnson, 2000).

This paper examines an integrated water asset management system within the context of this data acquisition cycle, identifies the generic constituents of asset management systems as well as their associated data requirements. A pragmatic approach to assist decision making with regard to determining rehabilitation priorities is introduced together with a case history where an Integrated Water Asset Management Systems (IWAMS) has been implemented.

Asset (infrastructure) management systems
A considerable amount of capital is generally invested in a water authority’s engineering infrastructure. Effective management of this infrastructure within financial and other constraints is required to ensure maximum benefit to the authority. This effective management needs a systematic approach incorporating relevant technical, financial and other factors, consisting of a comprehensive coordinated set of activities associated with the research, planning, design, construction, maintenance and evaluation of assets. This can best be achieved through management systems.

Before the water system can respond and the data acquisition cycle be completed, the data must be applied to facilitate the design, planning, operation and management of the water supply and distribution system.

Computerised management systems provide ready access to information, thereby fulfilling the needs of management by supporting the human decision making process, providing models which identify applicable types of data, and thereby limiting the capture and storage of unnecessary data. These management systems allow interactive and rapid access to data as well as assisting managers to retain control.

Although management of the asset base has historically been dependent on subjective assessments by those responsible for day-to-day operation and maintenance of the assets, there is a requirement for the asset base to also be managed from higher levels of the organisation in a way which will ensure that future investment delivers maximum benefit for customers and shareholders alike (Barnyard and Bostock, 1998).

A computerised asset management system generally comprises three major constituents: inventory; programmed action; and optimisation.

Inventory details include the identification, specification and situation of the assets that would typically be held in an asset register. Programmed action includes details of when, how, and how often (or how much) the asset should be inspected, maintained or tested. Optimisation indicates to the manager why and to what extent inspecting, maintaining or testing of the asset should be undertaken as well as indicating the extent of related potential benefits.

There is a need to implement a cost-effective and pragmatic water asset management system for water authorities in developing countries. The requirements and institutional capacity of water authorities in these countries are related more to the first two constituents of an asset management system, i.e. inventory and programmed action, than to the latter.
Integrated Water Asset Management System

The development of a computerised Integrated Water Asset Management System (IWAMS) was based on separate management systems initially developed in the mid-1990s, as well as on the experiences of their operational use in various developing countries. IWAMS has been enhanced and upgraded to ensure that it not only incorporates the relevant requirements of national and international codes of practice, but is also easy to use while taking cognisance of the application of basic principles.

The various IWAMS modules include the following.

- **Water meter management.** This module provides a computerised management system for all water meters, incorporating a water meter testing and maintenance programme as well as a record keeping facility.
- **Leakage control management.** This module provides the necessary guidelines to enable a water authority to collect data pertinent to the management of its water loss control programme.
- **Incident (complaint) management.** This module facilitates the registration and coordination of incidents received from the public and officials.
- **Water audit/balance.** Facilities are provided to undertake a water audit for the whole water authority as well as the water balance for individual water management districts. This is based on the summation of individual consumers as compared to the volume(s) recorded by management meter(s).

Each of the four modules are described briefly below.

**Water meter management**

Maintaining water meter records on a manual card and inventory book system requires considerable time and effort because of the number of units involved and because water meters do not always remain at one location during their useful lives but are moved, refurbished or repaired.

Computerised records which contain all relevant data facilitate increased productivity in the management of a water meter inventory. The availability of historic and current water meter data in an electronic format together with the statistics derived from such data, assists with the decision making process related to programmed actions.

Inventory details of this module include the following:

- **Identification.** The meter’s serial number and type are identified.
- **Specification.** The meter’s size and accuracy envelope is specified.
- **Situation.** The meter’s previous and current location addresses are recorded.

Data and facilities required for determining programmed action include the following:

- **When?** Installation, removal and testing dates with associated meter readings.
- **How?** Flow ranges for testing with associated calibration standards.
- **How often (or much?)** Reporting facilities help identify those meters requiring periodic removal and testing.

The optimisation of the meter refurbishment programme facilitates the establishment of the following (Noss et al., 1987):

- The optimal frequency for the removal of water meters of a specific size and type.
- The cost of water lost through failed, i.e. stopped, meters.
- The cost of water lost through inaccurate meters.

**Leakage control management**

This module facilitates the management of a programme for the reduction and control of the portion of unaccounted for water related to system losses.
Inventory details of the district provide a summary of the water supply and distribution network and include the following.

- **Identification** Provision is made for a unique district code as well as identification of the main consumer type.

- **Specification** The total length of pipelines, the number of properties and number of connections.

- **Situation** The name of the area, its parent area and coordinates of its centroid.

Programmed actions are related to leakage control surveys and include the following:

- **When?** Pertinent survey planning details with provision of actual completion dates to monitor progress as well as what remedial action was taken.

- **How?** The predominant leak detection method adopted and main cause of leaks discovered.

- **How often (or much)?** The empirical determination of the minimum night flow and its constituents provides a more accurate method of guidance for leakage control as well as justification for any remedial actions.

Optimisation theory developed by Shore (1988) can be applied with the aid of the district, financial, survey and statistical records. The following can be undertaken:

- A review of a leakage control policy through the determination of an optimal amount of expenditure.

- An optimal leakage benchmark for a particular district or city.

- The optimal number of surveys required per district.

### Incident (complaint) management

This module facilitates the registration and coordination of incidents received from the public and officials.

As a result of the registration of these incidents, IWAMS generates job cards for further action by the designated officials. On completion of the required task, details of the actions which were required to address the incident are captured by the system. Incident management reports can be generated to produce performance indicators related to various aspects, including the average time required to address incidents, number of outstanding incidents per time period, and so on. This module also caters for incidents for other services, e.g. electricity and sewers.

A link between the various modules of IWAMS and an example of such a linkage is that if the leakage survey team discovers a leak, it can be reported as an incident direct from the Leakage Control Survey Feedback screen.

Repairs to the network can therefore originate from such incidents. When damaged sections of pipes are removed during repair operations, provision is made within IWAMS for the recording of pipe conditions through measures such as pipe ring sample details, for example. This is a pragmatic approach which converts the external and internal depths of corrosion for various sectors of the pipe as a percentage of the wall thickness (Habibian, 1991). The subsequent corrosivity ratings derived from a history of pipe ring samples can be used to establish not only the corrosion potential of a district, but also an overall indication of the structural condition of the pipe network within a district.

### Water audit/balance

A water audit is an objective and comprehensive method of identifying, quantifying and reducing “lost” water. It is a management tool to help managers reduce water and revenue loss, reduce inefficiencies, plan renovations, and evaluate operations and water rates.

A computerised Water Audit System was developed for the SABS 0306 (1999) and it allows for the detailed identification by the water authority of matters concerning its water
related infrastructure, demographics of the area supplied and composition of the water authority’s organisation. In addition, information concerning water management practices is also required. The programme provides various statistics, performance evaluation parameters and a water balance computation. A detailed internal sensitivity analysis option is also provided in order for a water authority to conduct its own internal water audit.

The water audit/balance module of IWAMS incorporates the requirements of SABS 0306 (1999) and facilitates the determination of the level of unaccounted for water for the whole water authority. Other features include determination of the unit cost of leakage as well as the unit cost of unaccounted for water based on an apportion process described by Johnson (2000).

A water balance for individual water management districts can be established based on the summation of individual consumer’s demand as compared to the volume(s) recorded by management meter(s). The importation of electronic consumer demands from billing (account) systems facilitates this process. Exception reports indicate those management districts with abnormal water consumption.

**Network rehabilitation**

Many factors should be considered when the state and rate of deterioration of a water network is to be established. Some of these factors include the following.

- **Internal and external corrosion.** Externally the corrosivity of a soil in proximity to the pipes will have an influence on the leakage from buried pipes and fittings. Soil corrosivity maps facilitate the determination of the corrosion potential for different areas, as well as rehabilitation priorities (Habibian, 1991; Jarvis and Hedges, 1994). The composite corrosivity rating previously described can provide an overall indication of the structural condition of the pipe network.
- **Mechanical failures.** The movement of soils surrounding the pipe, traffic-induced vibrations and water pressure fluctuations within the pipe network can eventually contribute to structural failures. The shedding of internal protective coatings, as well as other foreign matter that is transported within the system, can result in the failure of water meters and pressure control valves. Water quality can therefore also have an influence on the wear of mechanical components such as meter bearings and hydraulically controlled valves.
- **Operation and maintenance.** The ability of a water authority to address aspects relating to the operation and maintenance of water networks in an efficient and effective manner also affects the rate of decay of such networks. An example of this could be that the longer a visible leak remains unattended the greater the potential is for further damage to occur through the undermining of the pipe bedding and so on.
- **Revenue spent.** The amount of money spent on repairs and replacements is indicative of the extent of the problem and can also be related to the number of incidents. In developing countries where non-payment of services is an issue, the limited budget available to address maintenance needs can be an important disabling factor.
- **Unaccounted for water.** The level of unaccounted for water as well as the magnitude of its leakage component is indicative of the state of the water network.

The deterioration of the asset can be modelled using mathematical, statistical and/or probabilistic models. However, in a developing country a simple and more pragmatic approach is usually required. An example of such an approach is the conversion of the various parameters to a common rating scale and representation of these ratings in the form of bar graphs on an area map of the network. Water mains rehabilitation priorities can then be established from the history of diverse data recorded by IWAMS to facilitate decision making.
Planning

The sustainable development of infrastructure (assets) requires dynamic inputs from a wide range of normative aspects as well as a range of dynamic technical inputs (Van der Walt and Johnson, 1999). IWAMS provides some of the information required for the planning of future assets and can be linked to planning systems. An example of such a system was a GIS based Dynamic Strategic Planning System (DSPS) developed by Van der Walt and Johnson (1999). The DSPS consists of a number of integrated modules that are used to evaluate the sustainability of a proposed development. These modules include infrastructure, hydraulic, environmental, cost, financial and resources modules.

Although IWAMS is a stand-alone software package, linkage with billing (account) systems and its potential linkage to planning systems, such as the DSPS, facilitates coverage of major portions of the data acquisition cycle.

Case history

A Norwegian-sponsored Water Conservation Project was implemented in Bulawayo, Zimbabwe in 1999/2000 with the objective of reducing water losses, upgrading the state of its water and sewer networks as well as implementing long-term water conservation options.

Losses from the distribution system was estimated at 20,000 m$^3$/day, or 23% of the demand during drought conditions.

Initially, IWAMS was installed with the main emphasis on the implementation of incident management as this was considered the most urgent requirement for improving the operations and maintenance of the water distribution system.

Although the IWAMS software consisted of a small part of the Water Conservation Project, it contributes significantly to the sustainability of the project through its ability to guide and manage flow of data from its capture through to its eventual application.

Some of the key aspects of this project included the following.

• The importation of approximately 100,000 m from the Treasury billing system into the IWAMS water meter management module to facilitate the management of the installation, removal and testing of water meters.

• The completion of water audits as specified by SABS 0306 (1999) with the aid of the water balance module.

• The management of leakage control surveys is facilitated through a comparison of minimum night flows (MNF) histories with set target levels.

• Production of reports that provide crucial information which facilitate decision making for leakage control and maintenance management.

Conclusion

Computerised asset management systems generally comprise the following three main constituents:

• **Inventory.** Includes details such as identification, specification and situation of the asset.

• **Programmed action.** Includes details of when, how and how often (or how much) the asset should be inspected, maintained or tested.

• **Optimisation.** Indicates why, and to what extent, inspecting, maintaining or testing of the asset should entail as well as an indication of the extent of related potential benefits.

The requirements and institutional capacity of water authorities in developing countries are generally related more to the first two constituents of asset management.

IWAMS fulfils the need for a cost-effective and pragmatic water asset management system for water authorities in developing countries. It is a modular system which can be implemented in stages together with external systems such as billing systems, which enhances the functionality of the combined system.
A case history illustrated how IWAMS facilitates the sustainability of a Water Conservation Project through the provision of a system that consolidates key facets of such a project as well as providing continued guidance for the management of the project.

References


