BEST PRACTICES FOR UTILITY-BASED DATA

A BEST PRACTICE BY THE NATIONAL GUIDE TO SUSTAINABLE MUNICIPAL INFRASTRUCTURE

National Guide to Sustainable Municipal Infrastructure
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Best Practices for Utility-Based Data
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FOREWORD

In spite of recent increases in public infrastructure investments, municipal infrastructure is decaying faster than it is being renewed. Factors such as low funding, population growth, tighter health and environmental requirements, poor quality control leading to inferior installation, inadequate inspection and maintenance, and lack of consistency and uniformity in design, construction and operation practices have impacted on municipal infrastructure. At the same time, an increased burden on infrastructure due to significant growth in some sectors tends to quicken the ageing process while increasing the social and monetary cost of service disruptions due to maintenance, repairs or replacement.

With the intention of facing these challenges and opportunities, the Federation of Canadian Municipalities (FCM) and the National Research Council (NRC) have joined forces to deliver the *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices*. The Guide project, funded by the Infrastructure Canada program, NRC, and through in-kind contributions from public and private municipal infrastructure stakeholders, aims to provide a decision-making and investment planning tool as well as a compendium of technical best practices. It provides a road map to the best available knowledge and solutions for addressing infrastructure issues. It is also a focal point for the Canadian network of practitioners, researchers and municipal governments focused on infrastructure operations and maintenance.

The *National Guide to Sustainable Municipal Infrastructure* offers the opportunity to consolidate the vast body of existing knowledge and shape it into best practices that can be used by decision makers and technical personnel in the public and private sectors. It provides instruments to help municipalities identify needs, evaluate solutions, and plan long-term, sustainable strategies for improved infrastructure performance at the best available cost with the least environmental impact. The five initial target areas of the Guide are: potable water systems (production and distribution), storm and wastewater systems (collection, treatment, disposal), municipal roads and sidewalks, environmental protocols and decision making and investment planning.

Part A of the *National Guide to Sustainable Municipal Infrastructure* focuses on decision-making and investment planning issues related to municipal infrastructure. Part B is a compendium of technical best practices and is qualitatively distinct from Part A. Among the most significant of its distinctions is the group of practitioners for which it is intended. Part A, or the decision making and investment planning component of the Guide, is intended to support the practices and efforts of elected officials and senior administrative and management staff in municipalities throughout Canada.

It is expected that the Guide will expand and evolve over time. To focus on the most urgent knowledge needs of infrastructure planners and practitioners, the committees solicited and received recommendations, comments and suggestions from various stakeholder groups, which shaped the enclosed document. Although the best practices are adapted, wherever possible, to reflect varying municipal needs, they remain guidelines based on the collective judgements of peer experts. Discretion must be exercised in applying these guidelines to account for specific local conditions (e.g. geographic location, municipality size, climatic condition).

For additional information or to provide comments and feedback, please visit the Guide at <www.infraguide.gc.ca> or contact the Guide team at infraguide@nrc.ca.

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EXECUTIVE SUMMARY

Good information is critical to the effective management of virtually any process. In the case of municipal water, wastewater, and stormwater utilities, there are literally hundreds of processes that cover a broad spectrum of service, technical, and business activities. All these processes require information and data that can include locations, dates, times, descriptions, and many different types of measurements. However, there are no commonly accepted information and data management standards or practices for municipal utilities to consult. As a result, many municipalities are storing these data in a wide variety of means and processes.

This best practice presents a foundation and a guide for municipalities that wish to begin the process of identifying, storing, and managing utility-based information and data. It is based on practices of public utilities and private organizations that have proven successful. Once implemented, it will form a strong and flexible foundation from which one can add increasing levels of detailed data which will allow for good utility management decisions.

This best practice begins by suggesting a common information framework for municipalities to use in managing information. It then presents a basic inventory of what information and data municipal utilities should be collecting that will result in better utility management (and continuous improvement initiatives in operations, maintenance, and capital investment activities). Finally, this best practice makes recommendations for storing and managing these data.

Seven distinct data categories for municipal utilities are suggested. Under each category, basic data elements (the data to be collected) are identified. While precise definitions of each data element and standards for measurement and collection would be valuable, this level of detail is suggested for future study. Many cities will already have progressed to this level of data management, but for those just beginning, this framework will provide a useful starting point.

Good decision making requires data that are reliable, current, and well understood. The acquisition process for these data must also be repeatable. This best practice makes recommendations regarding the need to document a municipality’s data model and specific information about the data collected. These activities are important to ensure the continued accessibility and integrity of any and all data. Weak data management processes can lead to inaccurate assumptions and possibly incorrect decisions.

There can be no doubt that computers and modern information technology have the potential to greatly improve an organization’s ability to manage information. However, this best practice has recommended data organization before software applications and technology. Purchasing a software package before organizing the data can lead to implementation time delays, loss of staff morale and undue expense.

After reading this best practice, each municipality should analyze its current data management practices in relation to the recommendations. Since this best practice was written to accommodate the needs of communities of all sizes, the actual software and hardware products a municipality selects will differ based on local budgets, current systems, and requirements. What is feasible for large cities will be quite different for small towns. Thus, specific brands of products or services are not suggested. However, the expectation is that, with these recommendations being shared among municipalities, this best practice will eventually bring many communities to a common data standard or framework. With this in place, these same municipalities will be able to make better management decisions, and to gauge, measure, and compare their continuous improvement via efforts for benchmarking internally and with others as they begin implementing other recommended best practices.

Finally, the work initiated in this best practice is by no means complete. It was recognized at the outset that best practices for utility-based data would evolve in an iterative and ongoing process. As municipalities increase their common level of data management sophistication, it is anticipated that further progress and revised editions of this best practice will be required, based on municipal feedback.

1. GENERAL

1.1 INTRODUCTION

These best practices are directed at the overall management of a municipal water, wastewater, or stormwater utility. They are meant to be a guide to assist the utility in the management of the data supporting the business and work processes related to the management practices (operations, maintenance, rehabilitation and replacement) of the infrastructure. If properly implemented, they will also facilitate the reporting of a utility's operations and maintenance (O&M) processes in a way that will allow inter-utility performance-based comparisons.

Any knowledge that can be exchanged is considered "information," and it is information that municipal utilities must rely on to provide services to the public. All information is based on some form of data, and the quality of these data has a direct bearing on the quality of the related information. The objective of this best practice is to lay the foundation that will facilitate better asset management practices (operations, maintenance, rehabilitation and replacement) through access to sound and accurate information.

As utilities continue the process of investigating O&M best practices, even basic intra- and inter-utility comparisons require a common understanding of the data that form the basis of the comparisons.

For some municipal utilities, considerable change in the way they gather, organize and manage data will be required. Other utilities may have already taken significant steps to improve the way data are collected, managed, and stored, and are advanced in their own strategic management of information and data.

It is expected that this best practice will provide the most benefits to utilities that:

- are beginning the process of organizing their utility data to improve operations and management;
- recognize that the data they rely on is not stored in any formal manner;
- have yet to collect the data needed to compare their practices and infrastructure with others;
- are beginning to move from paper-based to computer-based systems; and
- wish to have records that substantiate their due diligence for public safety and for continuous provision of all essential services.

1.2. SCOPE

Utilities must manage data that relate to all aspects of their business, including data about the assets, regulations, the environment, customers, employees, work practices, safety practices (risk management) and vendors. Some of these data are fixed (e.g., the diameter of a sewer or water main) while other data are transactional (e.g., the daily resource usage by a customer). The process of gathering, storing, and maintaining both types of data (i.e., fixed and transactional) will benefit from the definition of a common data management framework. However, the detailed framework for each area of data collection is not covered here. These best practices provide a foundation for the development of common data management policies that will assist utilities in functioning effectively and efficiently. They focus on the basic utility data requirements in terms of "what information is required" and "what are the initial considerations" in setting up a common data management framework.

The practices suggested within this document are considered to be:

- **Scalable**: These practices are applicable regardless of the size of the municipality.

- **System Vendor Independent**: These practices apply regardless of the software or type of operating system a municipality is using or considering using.

- **Technology Independent**: These practices do not depend on how data are managed, and they apply even in paper-based systems, although well-managed electronic systems can improve organization productivity.

- **Environmentally Independent**: Local climate and geography are not factors.

The objective is to lay the foundation for a common data management framework that can facilitate better overall utility asset management (operations, maintenance, rehabilitation and replacement) practices through access to good information. Although these best practices have been developed for water, wastewater and stormwater utilities, the concepts could be applicable to other areas of municipal infrastructure.

1.3 GLOSSARY

Activity — Work undertaken on an asset or group of assets to achieve the desired outcome.

Asset — A physical component of a facility which has value, enables service to be provided, and has an economic life greater than one year.

Asset inventory — A record or listing of asset information. It includes inventory, geographical, historical, financial, condition, technical, and financial information about each asset.

Asset number — A unique number that identifies every asset under a utility's management.

Capital cost — The budget designated for capital projects including reinvestment in the existing system and new investment for upgrades and expansions to handle growth. Capital projects cover equipment and large maintenance expenditures that cannot be funded through the operating budget.

Capital reinvestment — A project that substantially extends the life of the asset is considered a capital reinvestment. It is intended to minimize overall life cycle investment of existing facilities. It excludes expansions to handle growth and upgrades to a higher level of service.

Database — A database is an integrated collection of related data. Given a specific data item, the structure of a database facilitates the access to data related to it, such as an employee and all the courses he/she has taken.

Employee — The term refers to any labour that is not supplied by a private contractor.

Entity — The object or thing that a single table describes (subject of the table) is referred to as the entity.

Foreign key — A foreign key provides a way to refer to those unique values from another table.

Indirect costs — Costs associated with human resources, finance, legal, safety, payroll, information technology, etc., which support the wastewater treatment plant and collection system.

Logical independent — This means the relationship among tables, columns, and rows can change without impairing the function of application programs and ad hoc queries.

Object oriented database — A database in which the operations carried out on information items (data being stored as objects) are considered part of their definition. The relationship between similar objects is preserved (inheritance) as are references between objects.

Physical data independent — This refers to the representation of the data (i.e., what the user sees). It is completely independent of how the data is physically stored. As a consequence, physical storage can be changed or rearranged without affecting what the user sees or the logical database design.

Primary key — A primary key uniquely identifies a row in a single table.

Regulatory agency — An agency, typically of government, that issues the discharge and disposal licences for the utility. Other terms include governing agency and regulatory body.

Relational database — A relational database is based on the relational model. (Non-relational databases commonly use hierarchical, network, or object-oriented models as their basis.) A set of related tables forms a relational database. Each table consists of a set of rows and columns. Each row describes one occurrence of an entity. Each column describes one characteristic of the entity.

RDBMS (Relational Database Management System) — An RDBMS manages a relational database. It can come in several varieties, ranging from desktop systems (e.g., Microsoft Access) to full-featured, global, enterprise-wide systems (e.g., Oracle, Informix, Sybase, Microsoft SQL Server). Typically, most RDBMSs will use SQL.

SQL (Structured Query Language) — SQL is a language in which one "speaks" relational database. It is a high-level language for structuring, querying, and changing the information in the database.

System attributes — Information that describes infrastructure assets and the physical components of the utility.

Table — A table is a rectangular display of values as rows and columns.

Total direct O&M cost — The term refers to the sum of the actual O&M costs incurred in the operation of the treatment plant or water/wastewater/stormwater distribution or collection systems (excludes capital costs, indirect costs, transfers to reserves and debt/interest charges).

Unique identifier — A unique identifier is a data element, or value, in each row that identifies the row.

Value — A value is a single data element, such as the contents of one column-row intersection.

Work order — A specific instance of an O&M activity that consumes utility resources.

2. RATIONALE

A survey, conducted in late 2001, determined that utilities generally collect, store, and report information based on a number of internal O&M drivers. Examples of such "internal drivers" include:

- preparation of annual municipal budgets and long-range financial planning;
- submission of water quality reports to regulators;
- submission of Workers' Compensation Board/Workplace Safety and Insurance Board accident reports and statistics;
- calculation of wages and payments to staff;
- acquisition of equipment and materials required for operations and maintenance; and
- inventory management.

It was found that when drivers are stipulated by regulatory requirements (e.g., provincially regulated water quality results), the collected data tended to be consistent, of high quality (in terms of accuracy and reliability), and suitable for comparisons between different municipalities. Thus, the indirect impact of regulatory agency requirements has been the implementation of a number of discrete, pseudo "data standards" for utilities (in terms of what data to collect, when to collect and how to report). Unfortunately, in most areas of utility practice, no regulations or standards exist. Hence, for much of the information that is important to the efficient operation of a utility, data standards are not followed in spite of the need for quality data. In addition, in situations where pseudo-standards are followed, the standards are seldom complete or rigorous enough to meet the full management needs of the utility.

A common system of information and data standards is required and imperative to distinguish and determine process-based best practices. This best practice helps to determine:

- the data to be collected and stored;
- how to ensure the accuracy and integrity of the data;
- how to collect and store data; and
- how to retrieve data in a simple and practical way.

3. WORK DESCRIPTION

It was observed from the 2001 survey that Canadian utilities typically collect and retain data to varying levels both in support of their operations and for specific reporting requirements (e.g., regulatory compliance reports and budgets). However, there was little consistency in terms of the data types, fields, and how data are retained and maintained.

The 2001 survey identified a number of key data groups that are important for Canadian water, wastewater, and stormwater utilities, as shown in Figure 3–1. It should be noted that utilities may find they combine some of these groups. For example, flow and meteorological data might be categorized under "environmental data" in some data management and filing conventions.

Utility data organized under common categories and along common standards support utility operations and maintenance functions, and facilitate inter- and intra-utility comparisons (i.e., process benchmarking). It should be noted that the categories in Figure 3–1 are not application-based; rather, they are raw data repositories that, if planned correctly, support almost any utility application.

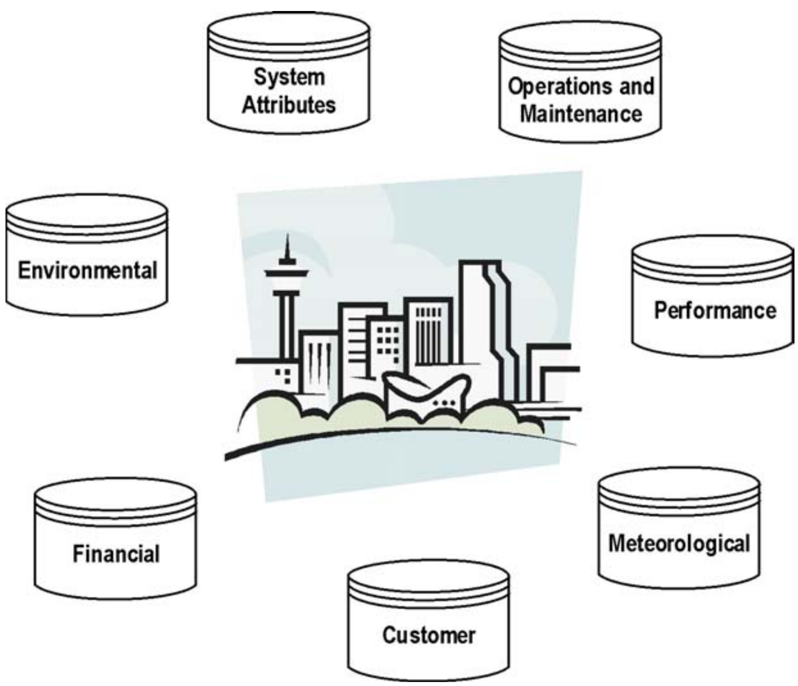

Figure 3–1: Key data groups for municipal utilities

3.1 Use a Documented Data Model/Data Structure

All data repositories, whether they are paper-based or computerized, must be supported by a documented data model (e.g., data structure). Such a data model includes the definition of the data types, the data formats, and data relationships between data types and naming conventions. In addition, any support data, such as coded data definitions (e.g., PCC = Portland cement concrete), must be documented. Vendor-supplied asset management systems typically employ proprietary data models; however, the data model documentation should be available to the subscribing utility. Also, there are non-proprietary, public sector models available to provide a foundation document such as:

- **MIDS (Municipal Infrastructure Data Standard) –** supported by the Tri-committee on Information Technology in Public Works (Ontario Good Roads Association, Municipal Engineers Associations and the Ontario Chapter of the American Public Works Association, <www.tricom.org>).

- **MIMS (Municipal Infrastructure Management Systems)** – a voluntary initiative focusing on infrastructure management issues for road, water, storm and wastewater systems available to small to medium size Alberta municipalities, <www.albertamims.org>.

- **LandXML –** an industry-driven, open XML data exchange standard that addresses the needs of private and public land development professionals, <www.landxml.org>.

- **PODS –** a Pipeline Open Data Standard, <www.pods.org>.

- **OGC –** Open GIS Consortium, <www.opengis.org>.

The data model and database should be highly normalized (i.e., data stored as a single occurrence at a specific database location only, rather than multiple occurrences throughout the database). Figure 3–2 illustrates a very basic model of the primary relationships between the key data groups.

3.2 Maintain Meta Data

Meta data are commonly referred to as "data about data." All data stored in the data repository must be supported by meta data. As a minimum, the following meta data should be maintained.

Entry Date: The date the data were entered into the repository.

Entered By: The name of the individual responsible for assigning the data to the repository.

Data Source: The source of the data (e.g., other database, application, field survey, etc.).

Data Acquisition Type: How the data have been acquired (e.g., field measured, estimated, vendor catalogues, etc.).

Data Confidence: An assessment of the confidence in the accuracy of the data (0: no confidence; 100: full confidence).

Data Accuracy: An indication of the expected accuracy of the data (e.g., +/- % or meters).

Note that as a minimum, the meta data should be gathered at the entity level (i.e., the record level), but may be gathered for individual attributes of an asset should there be several sources for the attribute data.

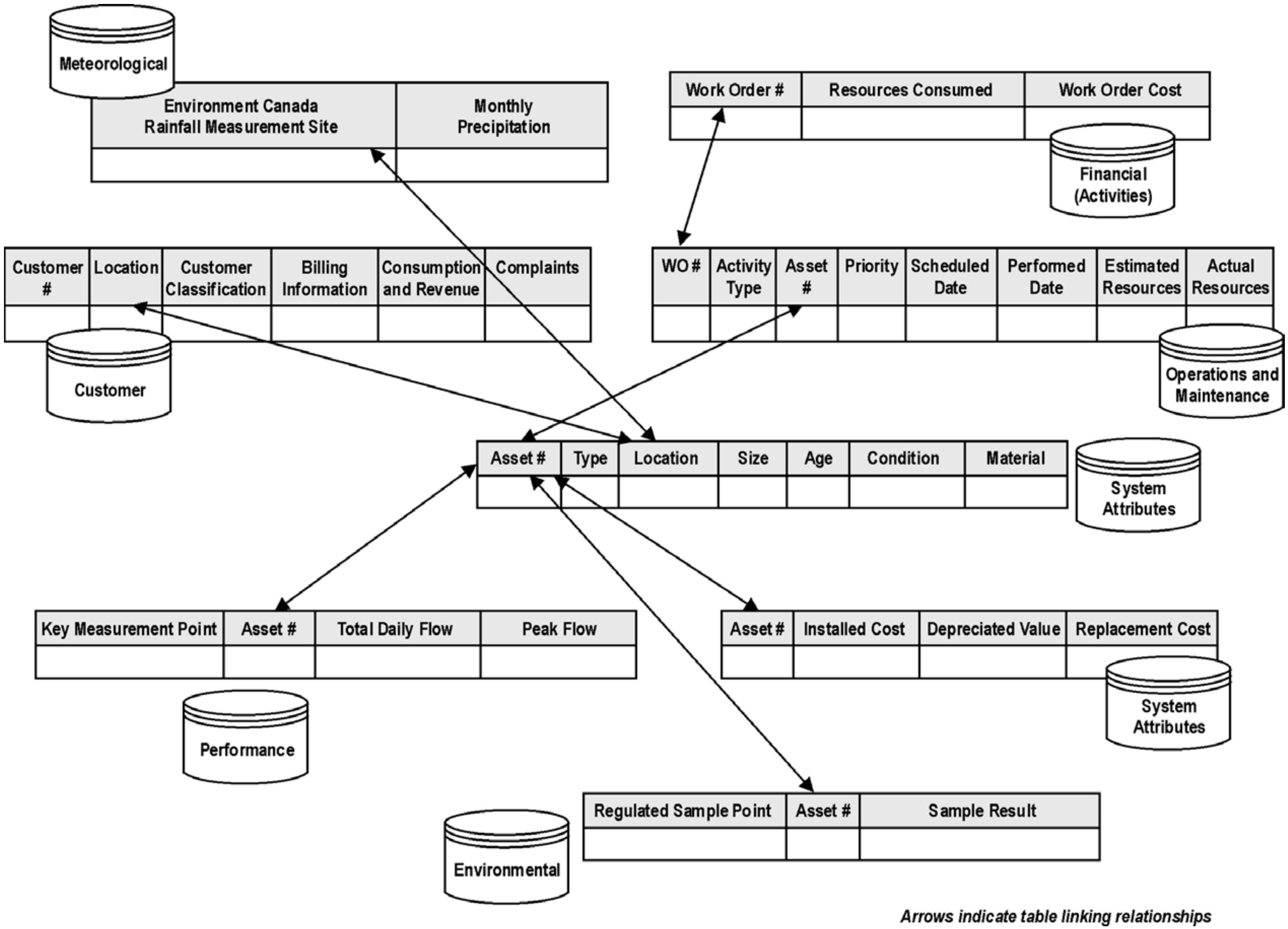

Figure 3–2: Primary relationships of base groups

3.3 USE DATA COLLECTION STANDARDS

All data in the repository that is the result of data collection or a data survey must be collected using documented standard survey procedures (e.g., pipe condition data taken from CCTV video). The documentation should detail the data to be collected along with the required procedures, quality assurance steps, accuracy requirements, and safeguards (in the case of failure, etc.). How data are collected, who is authorized to collect and certify the data, and the procedure for collecting and certifying the data are very important for building a data repository that can provide a solid and dependable source of information for the utility. Ideally, the data collection procedures should be standardized for all utilities in Canada.

3.4 USE STANDARD DATA UNITS

All data should be measured and stored in standard metric units.

3.5 USE STANDARD LOCATION REFERENCING

Location is a key attribute of much of the utility data. Options for location attributes range from very simple, field references to sophisticated coordinate-based references as identified in Table 3–1. The location-referencing scheme used by a utility may be a function of the utility's unique preferences and requirements. However, it is important that a standard approach be used consistently throughout the utility for all data requiring a location attribute.

Table 3–1: Location Referencing Options

Location Reference	Key Attributes	Possible Data Sources	Comments
Address	Address number, road name	Field survey, GIS	Useful reference for field crews; also provides a simplified street line based reference. Recommended that a standard street name list be used.
Pole reference	ID number, road name	Field survey, as-built drawings	Only useful if numbered poles are along street. Used by some larger agencies.
Distance marker reference	ID number, road name	Field survey, as-built drawings, hard copy records	Used by larger agencies, such as provincial departments of transportation.
Postal code	Postal code	Post office	Useful for general location of assets and association to a set of residents.
Block reference	Street name, from/to cross streets	Planning	Useful for quick reference to obvious attribute or event.
Global Sections	Section ID	Asset Management System	Road Segments or Sections that are assigned to all assets within the Right-of-Way that assists in accumulating assets for integrated priority programming.
Road/easement segment	Section/segment ID, street/easement name	Pavement Management System	Useful for coordinating with road programs.
Area reference	Subdivision, drainage area, etc.	Subdivision plans, model studies	Useful for modeling software and general location reference.
Relative linear reference	Road centre line distance from a reference, such as an intersection, the reference ID and type, offset distance from the road centre line, units used	Field survey, as-built drawings, hard copy records	Useful reference for field crews to locate and maintain an asset.
Geographic coordinates	X, Y, Z, projection used.	GPS field survey, GPS referenced video, total station	Requires GIS and extensive data processing to identify relative locations. Useful for location visualization and some analysis. Not as suitable for software-based priority program analysis as linear referencing.
Linear reference coordinates	Street or easement name or ID, distance measurement along centre line from street origin, +/- offset from centre line and vertical offset from surface or other datum if required	GIS, DMI-based survey, manual field measurements, digitized from as-built drawings	Places all assets on one absolute reference coordinate system, thus it is easy to extract from the database ANY or ALL assets between any two locations along a centre line. Can be maintained using GIS batch processing of geographic coordinate data.

3.6 Collect and Maintain Data

The following presents the minimum data that should be collected and managed within each data group.

3.6.1 Asset Attribute Data

High-quality asset data are critical for effective management of water, wastewater, and stormwater utilities. Since most costs and efforts performed by utilities relate directly to operating and maintaining assets, good asset and system attribute-related information, as well as a reliable means of storing and retrieving information is considered critical.

Best Practice Steps for Asset Data

The following are identified as key steps that will begin the process of managing asset-related utility data.

1. A complete inventory of all assets should be recorded and documented in a single repository. While the preferred approach is in a computerized database management system, a paper-based inventory ledger may still be acceptable, especially for small utilities.

2. Each asset must be provided with a unique identifier that is used by the entire organization (and by all computer applications). This allows information about assets to be stored under a single filing number (manually or electronically) in an easily retrievable format.

3. The asset location must be recorded based on a utility-wide standard location referencing system.

4. The relationship of assets to one another (topology) should be determined and stored in a suitable repository. It is important to maintain a single reference source that can be used to identify quickly the linkages and physical relationships between individual assets. (For example, where and how do interceptors connect, where are manholes placed in relation to a length of sewer, what pumps are associated with each pump station?)

5. O&M and rehabilitation activities should be related to the unique asset identifier. Updating these identifiers should be a standard and on-going process.

Recommended Asset Attributes

Asset attributes are data that describe the asset.

- **Asset ID**: This is the primary asset identifier (known as the primary key). Each utility asset must be assigned a unique identifier. The asset ID should never change through the life of the asset regardless of where it is located.

- **Asset Network or Group**: This is the parent group to which the asset belongs (i.e., water distribution, sewage pump station, etc.).

- **Asset Type**: This identifies the type of asset. Asset types include mains, valves, pumps, hydrants, etc. In electronic systems, such as spreadsheets and databases, "pick lists" can be used to control the use of asset type terminology.

- **Asset Location**: Location is a key characteristic of all assets and is essential for the management, analysis, and comparison of assets. It is recommended that the asset location information be stored in a single file or table to facilitate location-based comparisons regardless of the type of asset. There are many options for location attributes ranging from very simple, field references (e.g., street addresses), to sophisticated coordinate-based references. It is imperative that a utility set standard location reference attributes to be used for all assets. Some assets will require only a single point location (e.g., a fire hydrant), but other assets will need to be described by multiple points (e.g., a water main, which may be described by end-to-end points and depth).

- **Asset Dimensions**: Asset size will be specific to the type of asset. Water and sewer pipes will require length and diameter specifications.

- **Asset Design Capacity**: Design capacity of an asset is its hydraulic capacity, which is a function of its dimensions and properties (e.g.. roughness coefficient).

- **Asset Design Flows**: Design flows are key attributes for managing a utility. Typically, this information is generated using network modeling (e.g., hydraulic modeling), which considers different land usage scenarios (e.g. peak and average flows for current and future developments).

- **Installation Date**: This field determines the age or "serviceable life used" of the asset. The year the asset was installed or rehabilitated to a "new" condition should be recorded.

- **Asset Material**: The material the asset is made of should be recorded. This is required for asset management rehabilitation decisions (i.e. lining, cathodic protection, replacement, etc.). For example, lined cast iron, unlined cast iron and ductile iron can have different remedial or rehabilitation options.

- **Others**: A utility may select a wide range of other attributes associated with an asset, including maintenance notes, asset vendors, soil conditions and proximity to other utilities.

3.6.2 ASSET CONDITION DATA

A standardized approach to expressing the condition of assets should be adopted by the utility. The condition ratings of each asset should be maintained in a data repository along with the survey date and information on the rater. All ratings should be converted to a numerical scale or indices (i.e., 1 to 5, or 0 to 100 with the higher (or lower) number indicating an excellent condition). Indexes can be used in tracking degradation over time, and comparing the condition of different assets. Also, a numerical index facilitates the determination of composite indices, such as combining a hydraulic capacity index with a condition index and maybe a strategic importance index into an overall rating.

3.6.3 ASSET CONSTRUCTION, REHABILITATION OR RECONSTRUCTION DATA

Key data associated with the original construction and any rehabilitation and/or reconstruction must be maintained in a data repository. These data include the asset ID, the date of the activity, the standard activity name or ID, the cost of the activity, the name of the organization that did the work, the name of the primary contact or project manager and comments.

3.6.4 ASSET PERFORMANCE DATA

Performance data in terms of flow (e.g., measured flow, pressure, pipe roughness, etc.) are most commonly used to support the activities of municipal water, wastewater, and stormwater utilities.

Best Practice Steps for Performance Data

The following are identified as initial steps in utility flow data management:

1. Establish an inventory of all flow measurement points. As a starting point, influent/effluent flows at major nodes including water and wastewater transfer points (where the product changes ownership or responsibility), are identified as key points of interest.

2. Utility operational needs require a range of flow measurement types (including average, maximum, minimum, and instantaneous, for real time and greater periods). The flow measurement needs required are:
   - daily flow totals at key measurement points (item 1 above); and
   - peak flows at key measurement points where appropriate (item 1 above).

3. Measurements should be in standard metric units.

4. Other key flow related performance data include:
   - potable water, including the measurement of water loss (unaccounted for water) and individual customer water usage by customer type (i.e. residential, industrial, institutional or commercial);
   - wastewater, including inflow and infiltration, flood complaints (e.g., flooded basements (surcharge) and overflows (combined sewer overflow (CSO) and sanitary sewer overflow (SSO))); and
   - stormwater, including storm flows (time-history), surface flooding (surcharge) and stormwater quality (time-history).

Recommended Performance Attributes
The following minimum suggested performance data are important in the management of water, stormwater, and wastewater utilities. Utilities must still determine the appropriate key measurement points, based on their own requirements. (Many utilities will choose to collect and manage a great range of flow measurements, and these can be added to the attribute table at any time.)

- **Key Measurement Point**: The utility should identify key measurement points. Each measurement point should be assigned a unique ID.

- **Asset ID**: Each measurement point should be related to the associated asset, using the unique ID of the asset. The assets are based on the selected key measurement points (and may include such things as mains, reservoirs, or water meters).

- **Total Daily Flow**: Total volume of water (wastewater) in a 24-hour calendar day.

- **Peak Flow**: Peak flow rate in a period of time (where appropriate or required).

- **Rainfall/Precipitation**: Local data supplemented by Environment Canada records.

3.6.5 OPERATIONS AND MAINTENANCE DATA

For effective management, O&M requires transactional data regarding resource usage (e.g., labour, equipment, materials, contracts, etc.) for defined activities against individual assets. For the most part, utilities perform very similar operations and maintenance activities. The difference is in the methodology, the level of effort, and the frequency in performing the activities.

The process of determining an O&M best practice is based on activity comparisons using specific performance metrics. This requires a common definition and understanding of each activity. Once a standard definition of all O&M activities has been determined, the cost of performing these activities (through the consumption of resources including time, vehicle and equipment use, material, contract services, supplies, etc.) can be determined.

With good information management practices and support systems, utilities can associate O&M activities with specific assets to determine the effectiveness (Is the asset doing the job it was designed and installed to do?) and the efficiency (Is the asset costing more than it should?) of the asset. By making comparisons of alternative ways of performing activities, best practices can be identified, implemented, and monitored to ensure the anticipated improvements are realized.

Operation and Maintenance staff also needs to know which assets have critical importance. Work is currently underway in both Canada and the United States involving studies that identify “backbone infrastructure”, “critical infrastructure” and “critical customers” that can aid the utility in both responding to customers needs better and in prioritizing capital reinvestment strategies. Each utility however, should establish a policy dealing with performance criteria as part of an overall asset management plan.

Best Practice Steps for O&M Data

The following best practice steps will begin the process of measuring and comparing O&M activities related to assets.

1. A standard definition of all O&M activities must be developed. Note that it is imperative for purposes of defining national O&M best practices that these definitions be standardized for all Canadian utilities wishing to engage in Guide activities.

2. All individual instances of a performed activity by a municipal utility should be recorded against a uniquely numbered work order.

3. Work orders should be planned and managed according to good maintenance management practices.

4. All work orders should be associated with specific assets.

5. All available hours (defined by total O&M staff times the number of hours in the defined period) should be accounted for, including:
   - actual hours worked;
   - vacation, holiday, sick leave, Workers Safety Insurance Board (WSIB) usage, training and other non-working time; and
   - supervision and other indirect time.

6. All other cost items related to the work (equipment, materials, contractors) should be accounted for.

7. Activity types should be grouped under the following categories:
   - wastewater (treatment plants, collection system including service connections or laterals, pump stations);
   - stormwater (retention and storage, treatment, conveyance and pumping); and
   - potable water (water source/watershed management, treatment plants, distribution system including service connections and meters, pump stations and reservoirs and elevated tanks).

The following briefly describes the minimum data that should be associated with O&M activities. Any utility considering the implementation of maintenance management is advised to consult the many technical resources that are readily available (AWWA and AwwaRF publications). Utilities that have already implemented maintenance management systems (and the associated work processes) should have no difficulty in obtaining the information discussed in this portion of the best practice.

Recommended Work Order Attributes
The attributes of a work order describe the work to be performed, the asset(s) the work relates to, and the resources consumed by the work. It should also include information that will assist in planning and managing the work. The following attributes are considered the most important for infrastructure O&M work management.

- **Work Order ID**: This is the primary work activity identifier (known as the primary key). Every activity that consumes utility resources should be recorded as a separate work order. The work order ID must be unique and should never change.

- **Activity**: Activity is an agreed upon definition of an action to be performed. It is a fundamental accumulator for costs and resource usage. Utilities tend to perform a limited number of activities many times on a large inventory of assets. A standard list of activities should be defined and controlled by the utility.

- **Asset ID**: Work orders should be associated with specific assets using assigned asset IDs. With time, the maintenance history of specific assets can be used to assess asset management strategies.

- **Priority**: The urgency of the work order should be recorded. This allows the work to be planned and scheduled in the most efficient manner possible. A utility should consider a standardized approach for assigning a limited set of priorities based on the utility’s maintenance objectives, but should include preventive, reactive, and scheduled and unscheduled priority assignments.

- **Actual Start and End Dates**: The dates the work order was actually started and completed need to be recorded. This information will allow utilities to manage work schedules and maintain records of down time.

- **Actual Resource Usage**: This information records the resources actually used in completing the work order. Actual resource usage will also allow a utility to calculate the actual cost of O&M activities based on a general formula of the quantity of resources consumed times the unit cost of each resource.

3.6.6 FINANCIAL DATA

All utilities are required to prepare financial statements in conformance with the accepted accounting principles for local governments as recommended by the Public Sector Accounting Board of the Canadian Institute of Chartered Accountants (CICA). Note that details regarding this standard can be obtained from CICA directly. Within this standard, there are alternative approaches to budgeting and management (cost) accounting. In managing utility infrastructure, two financial cost factors are of utmost importance: the cost of activities and the value of the assets.

Determine the Cost of Activities

Most municipal and utility organizations still manage the cost of operations separately and distinctly from their work order management processes. The 2001 survey indicated that very few municipalities have integrated their financial and work management systems, though this is an objective of many.

Most municipalities and utilities plan their financial management processes and systems around the need to develop an annual budget. This involves allocating costs around departmentally based cost centres rather than work-based activities. While this provides a document for municipal councils (and, ultimately, citizens) to see where their dollars are being spent, it is not a good tool for activity management.

The largest challenge to implementing a cost-tracking process based on activities is the treatment of indirect costs. For municipal utilities, indirect costs typically include normal municipally performed services that relate to all municipal departments, such as human resources, accounting, IT and legal services. In most cases, these services are allocated to municipal departments based on a formula. The other complicating factor is the range of municipal services that can be considered direct or indirect. Municipalities do not treat services such as fleet (vehicles and equipment), engineering, and information technology consistently. While full activity-based costing is desirable, identifying direct O&M costs, as a first step, is still a valuable process since utility managers have some degree of control over direct O&M costs and have better access to direct O&M cost data associated with work orders. Activity-based comparisons to measure the impact of O&M-related best practices will also be valid.

Best Practice Steps for Financial Data
All utility direct costs should be recorded using work orders. (The work order is the tool for associating costs to activities and assets). A common definition of direct costs is required among municipalities. The following is proposed.

Total Direct O&M Costs: Sum of the costs incurred in operations and maintenance activities.

- Includes operations labour, vehicles and equipment, material and supplies, contracted operations costs, laboratory, industrial source control, operations administration, operations staff training, energy, water, permit fees, property taxes, and rent.

- Excludes indirect costs associated with human resources, finance, legal, safety, payroll, information technology, customer billing, supervision, corporate administration, customer services, liability insurance, facilities management, capital costs, transfers to reserves, debt/interest charges, etc., which support the treatment plant and linear system.

Recommended Activity-Based Costing Attributes
The basic principle of activity-based costing is simple and logical. However, it is recognized that installing an activity-based costing system in any organization can be very complex, and there are numerous allocations of resources (and ultimately costs) that are shared among many activities. This typically requires a more subjective process of allocating indirect costs. The following data are recommended as a starting point. Utility accounting staff and expertise in maintenance management will provide the required level of detail to complete the process.

- **Work Order ID**: A unique identifier for each work order. This is the primary work activity identifier. Every activity that consumes utility resources should be recorded as a separate work order.

- **Resources Consumed**: What individual resources did the activity require? An activity can be expected to consume a range of materials, labour, contracted services and equipment. Each resource and quantity should be recorded separately under the same work order (e.g., hours of labour, number of parts, hours of specialized equipment, etc.).

- **Work Order Cost**: The direct cost of the activity can be determined by totalling the cost of all the consumed resources.

Determine the Value of Infrastructure Assets
To manage infrastructure successfully, a utility must have current data regarding the value of assets under its management. This will become increasingly important as the GASB 34 (Governmental Accounting Standards Board

Statement No. 34) in the United States will influence financial practices in Canada. Ontario's Bill 175 (Sustainability of Water and Wastewater Systems) will require every municipality in Ontario to report annually on the value of their assets and the amount of money reinvested in the assets to maintain a state of good repair. Many municipalities have only limited data for the value of their infrastructure. Data for construction costs have not always been connected to the asset after project completion (whether construction by the municipality or through contributed assets from private developers). Utilities sometime estimate their asset value based on replacement costs derived from current construction cost data.

Recommended Asset Valuation Attributes
The following data are recommended to determine the value of assets. These data are used in developing infrastructure renewal and replacement strategies. Even though precise information is preferred, estimated valuations as a starting point can help with long range financial planning and basic asset management planning.

- **Asset ID**: This is the primary asset identifier.
- **Installed Cost**: This is the cost of the asset at the time of installation. It serves as a basis to help determine the remaining asset value.
- **Date of Installation**: This is the date the asset was installed or was put into service and is used to evaluate the installed cost in terms of today's values.
- **Depreciated Value**: This is the current value of the asset given its current condition (and age) and should be calculated from a standard formula.
- **Replacement Cost**: This is an estimate of the cost to replace the asset in its current location.

3.6.7 METEOROLOGICAL DATA

The 2001 scan revealed that only some municipalities and utilities collected and stored weather-related data (most notably rainfall). These are not "performance" data, but relate more to the local conditions affecting a utility.

Best Practice Steps for Meteorological Data
At a minimum, it is suggested that municipalities collect and store local rainfall/precipitation data supplemented by Environment Canada daily and monthly precipitation data (in metric units). It may be sufficient to ensure that access to historical Environment Canada data is available. Rainfall data are useful as an indicator of local conditions and to assist utility planners in the design of future facilities and infrastructure. It is also an important factor in wastewater system inflow and infiltration. For site-specific or event-specific

analyses, more detailed data (e.g., rainfall at 5 minute time intervals or weather radar data) are required.

3.6.8 Environmental Data

Most environmental data are gathered for reporting purposes (i.e., to regulatory authorities). As was observed in the 2001 survey, all environmental regulation authorities are provincial and, as such, environmental regulations and mandatory reporting requirements differ substantially from province to province. Due to stringent regulatory requirements, environmental data are readily available from utilities. These data are generally of high quality (and, in many cases, certified).

Environmental data for potable water utilities will be based on the need to meet regulated reporting requirements. These can include (but are not limited to) raw water and treated plant water quality test results, compliance with water permits/regulations, contaminant concentration in residuals, aquifer levels, spill events, and water quality test results from the distribution system.

Environmental data for wastewater utilities will be based on the need to meet regulated reporting requirements. These can include (but are not limited to) effluent quality, contaminant concentrations in industrial discharges, contaminant concentrations of raw sewage and effluent, the number of surcharges or overflows from the plant, contaminant concentrations in treated biosolids, the number of bypasses of the plant, and contaminant concentrations in surcharges or bypasses.

Best Practice Steps for Environmental Data

Environmental compliance reports should be available to all utility staff and the public through the utility Web site or other easily accessible sources. Some provinces (specifically Ontario) are consolidating environmental compliance reports in a single database.

Recommended Environmental Attributes

The following data are recommended to assist in the management of flow and quality data.

- **Regulated Sample Point**: The utility should identify regulated sample points based on the regulation requirements. Each sample point should be assigned a unique ID.

- **Asset ID**: Each sample point should be related to the associated asset, using the unique ID of the asset.

- **Sample Result**: Regulated sample results, including date, time and analytical protocols.

3.6.9 Customer Data

All utilities need customer-related data for billing purposes and managing customer relations. Customer data include customer billing information, water service material type (i.e., lead, copper, PVC, etc.), consumption data, feedback from customers (e.g., water complaints), the number of flooded basements, service requests, industrial sewer-use permit information, violations, results from customer surveys, response times, logged customer calls, and population served.

Best Practice Steps for Customer Data

At a minimum, utilities should maintain the following customer classes.

- Water customers
  - residential (connection locations, accounts, meters);
  - industrial, commercial, institutional (including connection locations, accounts, meters, pipe material, size and type);
  - wholesale (for regional or bulk suppliers); and
  - agricultural (water for irrigation).

- Wastewater customers
  - residential (connection locations, accounts); and
  - industrial, commercial, institutional (connection locations, accounts, overstrength permits, codes of practice).

Although not all water customers are metered in all jurisdictions, water consumption based on flow is the best way to make consumption-based comparisons.

Utilities should associate revenue to customer classes. This facilitates the ability to determine the adequacy and equity of specific rates on customer classes. Revenue received from other sources (e.g., tax based, connection fees, other charges) should be recorded separately.

Recommended Customer Attributes

Good customer service requires good information about each and every customer. The following customer attributes are recommended as a minimum.

- **Customer ID**: Each customer should be assigned a unique ID. All customer-related data should be associated with this key and stored in an electronic system.

- **Customer Location**: Location is a key characteristic of all customers and is essential for the analysis and comparison of customer information. In most cases, field references, such as addresses, are sufficient.

- **Customer Classification**: This is based on the classification grouping decided by the utility.

- **Billing Information**: This can include a wide range of information about the customer that is related to billing and customer relations. This may include basic information, such as name, contact phone numbers, and posting address (if different from field reference). Other data may include the payment record and special instructions.

- **Consumption and Revenue (Period Charges)**: These actual billing details for the customer account are based on the utility's payment policy and any outstanding balances. By associating revenue with customers, it is possible to conduct detailed revenue analysis on various customers and customer classes.

- **Complaints**: The number of complaints received in a period is one indicator of service quality. However, many utilities do not have well publicized customer service telephone numbers. In these cases, a low number of complaints might not be an indicator of service quality; rather, customers were not able to contact the utility in a convenient manner. The only way to support meaningful complaint analysis is to ensure that the utility is using a highly visible customer complaint gathering process.

  However, the value of customer complaints and feedback should not be underestimated in terms of value to the utility in the following ways:

  - **Operations**: Customers can provide the utility with near real time communications regarding system failures.

  - **Setting Priorities**: Customers can provide input (in the form of complaints) to capital project priority setting.

  - **Measures of Performance**: Customer complaint volume trends can be an indicator of utility performance. An increasing number of complaints can indicate an erosion of service levels (at least of perceived service levels).

  Once a customer response program is developed, it is recommended that the following customer complaint incidents be recorded:

    - low pressure (potable water);

    - water outage (potable water);

    - water quality complaints including color, odour, taste, lead level readings, etc. (potable water);

    - basement flooding (wastewater, stormwater);

- surface flooding (stormwater); and
- sewer odour complaints (wastewater).

Complaint incidents should be linked to the customer and, ultimately, to the asset responsible for the complaint.

3.7 STORE DATA

Information (and the data that make up information) is essential for good utility management decisions. The better a municipality is at managing its information, the better its ability to make good decisions. The most important tool available to improve the efficiency of managing information is the computer. The dramatic reduction in the cost of computing over the last 25 years has made this technology readily available to even the smallest municipality. Best practices in information management include the use of computers at almost every stage. However, the implementation of computer and information technology into work areas for the first time, or even to replace computerized systems that are obsolete are not easy. It is a complicated and challenging process that involves technical challenges, as well as managerial and human resource challenges of the highest order. Many system implementation projects have failed as a result of underestimating the complexities of these issues.

Success in managing infrastructure is closely tied to a utility's ability to manage information. While it is possible to create and manage an infrastructure information management system, such as described in this best practice in a purely paper-based system, it will not be as effective or efficient as a well conceived computerized information management system. Therefore, utilities are encouraged to use computerized information management systems. The challenge to utilities is to determine an appropriate strategy for installing computerized data management tools in a manner and scale that best meets the requirements of the municipality.

3.8 MANAGE DATA

This best practice provides the basics on information management. Selected data management guidelines that pertain to the collection and storage of the data are presented to help utilities in the process of establishing an information technology plan. Other recommendations, which are specific to more complex database systems, are presented in Appendix B.

All data must be well documented and described along with the procedures for gathering or collecting/using/maintaining the data. Ideally, data should be collected and stored once and only once in a corporate repository. These data should then be available for any and all approved utility applications.

Electronic spreadsheets, such as Microsoft Excel, are a tool for data collection and storage within utilities. However, the spreadsheets are usually created by individuals for very specific needs, with no consideration of the needs of the organization's data repositories.

While the continued use of spreadsheets is not discouraged, greater care in the management of spreadsheets as a municipal data repository (and as official records subject to freedom of information legislation) is encouraged. Documented standards regarding the creation, storage, management, and use of the spreadsheet files are recommended.

Larger, multi-departmental municipal organizations are encouraged to consider the wider use of commercial databases (file-based, relational, or object oriented) as the primary tools to manage all data.

Adequate security safeguards to ensure that data cannot be changed or tampered with through unauthorized or unanticipated ways must be implemented. These safeguards must be effective in protecting the data, but must also allow authorized access to the data for various applications. These safeguards will depend on the data technology in use. For example, paper-based systems can be protected by secured filing systems with built-in access controls in place. Databases developed in Excel and other simple electronic tools will need to be protected at the electronic file and directory levels. Advanced databases have the ability to protect data through user access limits.

Ensure that a data security system is in place. Data security is important in database management, because the information stored is a valuable commodity or it would not be kept. It needs to be protected from unauthorized use (i.e., seen, changed, or removed by anyone not authorized to do so). It typically does so with user IDs and special users. In the low-tech world of a single PC user or files stored on a PC's hard drive, a lock and key are sufficient. In a larger shared system, some of the following security items should be addressed.

- If the database is large and will be shared over various servers or as part of a network, ensure that a firewall is in place.

- Ensure that a backup/recovery system is installed and well understood. It can use such things as write-ahead logs where the change is recorded in the log before any change is made in the database itself. This ensures that data can be recovered completely in case of a failure by playing back the log.

- Ensure that multiple use and sharing principles are developed.

- Ensure that data integrity is maintained. Data integrity refers to the accuracy and consistency of the data in the database. Database software would ideally provide a variety of mechanisms for checking on data integrity. The most basic level of integrity tool ensures that the database system is able to guarantee that a value being entered is the correct data type and is within the range of values supported by the system. A domain constraint should also be built into the system. A domain is the set of logically related values from which the value in a particular column can be drawn.

- There should be entity integrity, which requires that no component of a primary key be allowed to have a null value. (Remember that the primary keys serve as unique identifiers that are critical to maintain.)

- There should be referential integrity, which concerns the relationship between the values in logically related tables. In a relational model, it means guaranteeing the logical consistency of the database by making sure the values of a primary key and the foreign keys that point to it always match.

- Ensure that integration with other corporate databases is possible if required.

- Ensure single entry of any data.

- Ensure data disposal protocols are in place with systems to track change history.

4. ISSUES REGARDING COMPUTERIZATION

Information management and information technology (computerization) are closely tied. However, the terms are not interchangeable. Successful information management through data collection and storage must start with information organization before computerization. Unorganized utilities that implement computerized systems as a means of organization will be disappointed in the results, with most of their investment lost. However, given the large amount of information and data required by modern municipal utilities, and the high degree of functionality available from computerized systems, such as a geographical information system (GIS) or computerized maintenance management system (CMMS), a well-organized municipality can make significant productivity gains through computerization and automation.

The focus for information management is first and foremost on business requirements. The recommended starting points in determining a strategy to improve information management within a municipal utility starts by defining a clear plan. The plan should include scope, budget, timing and change management (ensuring buy-in and support by senior management, council, staff and end users)

Once a utility's business requirements for information and data are organized, implementation of automation tools, such as a CMMS or GIS, becomes easier, and the utility can expect greater benefits. As in most management functions, the degree of organization and the ability to be proactive are closely tied.

Appendix B provides assistance to municipalities considering the implementation of more complex computerized database systems.

5. RECOMMENDATIONS

This best practice recommends that agencies responsible for potable water treatment and distribution, wastewater collection and treatment, and stormwater management use standardized definitions and codes for utility management data.

Within the surveyed Canadian municipalities, there were no references to the same set of data standards. In fact, the literature search revealed that, while many standards exist for specific purposes (e.g., vendor-supplied equipment and product procedures), none of these standards was used consistently throughout the surveyed sample. In some cases, industry associations, such as the American Water Works Association and the Water Environment Federation, have also developed standard definitions, glossaries, and dictionaries of terms. Most municipalities have developed local definitions based on their needs. These local definitions continue to make infrastructure data comparison and management difficult.

APPENDIX A: BASIC DATA STRUCTURES

The following tables display a suggested basic level of utility infrastructure data attributes that should be collected and stored.

Table A–1: Basic Asset Attributes

Primary Key	*Asset Attributes*						
Asset ID	Type	Location	Size	Install Date	Condition	Material	Manufacturer

Table A–2: Basic Work Order Attributes

Primary Key	*Work Order Attributes*						
WO ID	Activity Type	Asset ID	Priority	Scheduled Date	Performed Date	Estimated Resources	Actual Resources

Table A–3: Direct Cost of Work Orders Table

Primary Key	*Acitivity Based Costing Attributes*	
Work Order ID	Resources Consumed/Utilized	Work Order Cost

Table A–4: Asset Valuation Table

Primary Key	*Flow Attributes*		
Key Measurement Point	Asset Number	Total Daily Flow	Peak Flow

Table A–5: Performance Table

Primary Key	*Asset Valuation Attributes*		
Asset Number	Installed Cost	Depreciated Value	Replacement Cost

Table A–6: Precipitation Table

Primary Key	*Precipitation Attributes*
Environment Canada Rainfall Measurement Site	Monthly Precipitation

Table A–7: Environmental Attribute Table

Primary Key	*Environmental Attributes*	
Regulated Sample Point	Asset Number	Sample Result

Table A–8: Customer Attributes Table

Primary Key	*Customer Attributes*				
Customer Number	Location	Customer Classification	Billing Information	Consumption and Revenue	Complaints

APPENDIX B: ASSET AND MAINTENANCE MANAGEMENT SYSTEM CHECKS

This appendix provides a checklist for municipal utility infrastructure data. Although principally geared for use with computerized database systems (both large and small PC-based systems), the checklist may be useful in developing and establishing paper-based systems.

- Ensure that the maintenance management system (MMS), whether computerized or not, tracks all work against the infrastructure assets.

- Ensure that any work order (WO) system of the MMS has each work order attached to a specific infrastructure element (i.e., work on a broken main has the work order attached to that segment of main).

- Ensure that each segment of all linear systems is divided into nodes (break points), which can be used with a GIS or laptop GIS or manual plan system.

- *Always* start with a complete inventory of infrastructure assets.

- Use distinct, unique identifiers for each infrastructure element.

- Identify all infrastructure elements, with a tag, bar code, global positioning system (GPS), street address, etc., to ensure the unique identifier is maintained and consistent in the field.

- Use hand-held field data collection devices which upload information in the morning and download information at night with minimal paperwork. Data entry is encouraged as it allows the use of bar codes for identification of the infrastructure element without manual entry.

- Encourage the use of databases wherever possible. In today's environment, PC desktop packages, such as Microsoft Access, can be integrated with desktop GIS packages, such as Arcview, to provide a full package of tools to carry out asset management even for the smallest utilities.

- Use the ability to integrate all the different data collected on any single infrastructure element or group of elements. That is, the system should be capable of displaying hydraulic information, water quality information, physical information, and maintenance information available on any set of pipes based on the unique identifier or primary key.

- Use a common location referencing scheme to prioritize multiple utility rehabilitation needs (i.e., look at water, sanitary, storm, roads, sidewalks, and traffic signals together when making decisions).

- Ensure that work orders include, at a minimum, manpower (hours and cost), equipment, materials, tools, and work details, for entry into the system.

- Ensure the system can provide reports and summaries to assess the condition, performance, and costs, both as text and as graphics.

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