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City of Nanaimo Water Audit

Final Report

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KWL Project No. 0566.068-300

Prepared for:

City of Nanaimo

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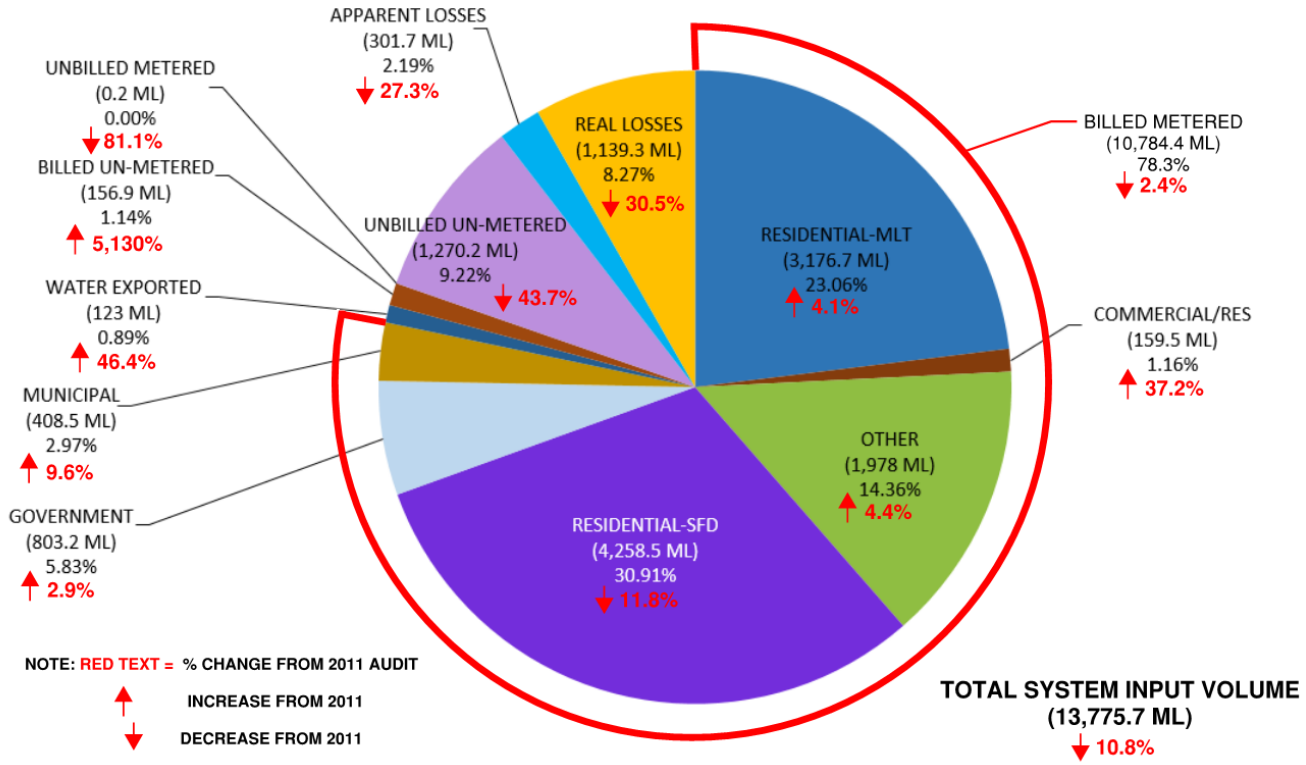
Executive Summary

KWL completed a top down AWWA M36 water audit on one year of data starting from August 1, 2015 and ending on July 31, 2016. The start and end dates of the audit represent the most current and complete one year period of customer meter reading data as of August 2017.

The results of the audit are presented on the chart below together with how each component has changed from 2011:



The City made positive changes in every aspect of the water audit when compared to 2011.

The total water produced during the audit period was 13,775.7 ML, down 10.8% from 2011.

79.2% of the water produced is billed to customers (revenue water = billed metered + water exported). As a percentage of water produced each year, revenue water is up 6.6% from 72.6% in 2011.

The audit revealed a very low level of real losses, 1,139.3 ML, corresponding to an infrastructure leakage index (ILI) of 1.13. This represents a 30.5% decrease in the level of real losses estimated for 2011 and is near the technically lowest level of losses that can be achieved.

There is no room for improvement to be made in real loss reductions. The potentially recoverable volume of leakage, 131.3 ML, costs the City approximately $4,100/year, and would likely not be reduced with additional

leak reduction effort. The majority of this leakage is likely attributed to numerous very small leaks on service connections.

The cost of apparent losses is valued at $716/ML and the cost of real losses is valued at $31.6/ML.

The volume and cost of losses both real and apparent are provided below:

Cost of Apparent Losses by Source in 2016

Water Loss Type	Yearly Volume (ML)	Yearly Cost ($)
Apparent Losses		
Unauthorized Consumption	34.4	$24,600
Customer Metering Inaccuracies	240.0	$171,800
Systematic Data Handling Errors	27.3	$19,500
Total Apparent Losses	**301.7**	**$215,900**
Recoverable Real Losses	131.3	$4,100
Total (recoverable) Real Losses	**131.3**	**$4,100**

The cost of customer metering inaccuracies remains the largest yearly water loss cost.

Improvements in the volume of apparent losses from 2011 to 2016 are largely attributed to a reduced estimate for the volume of systematic data handling errors.

The 43.7% decrease in un-billed un-metered consumption is attributed to the removal of the treated water blow-off to the decommissioned raw-water Reservoir #1.

Single family indoor water use is estimated at 182 L/capita/day in 2016, down from 198 L/capita/day in 2011; an 8% reduction. Seasonal demands are estimated to have decreased by 6%.

Recommendations

We recommend the City continue ongoing efforts and budgets, recommended in the 2011 Water Audit, for the replacement of customer meters.

We recommend the City complete updates to the water audit on a yearly basis. This work is estimated at $10,000 / year.

1. Introduction

The City of Nanaimo (the City) has retained the services of Kerr Wood Leidal Associates Ltd. (KWL) to complete a 2016 top-down water audit to gain an understanding of where and how water is being used and what level of losses, both apparent and real are occurring. The audit follows the guidelines of the AWWA M36 top down water audit.

This work follows a 2011 Water Audit that was completed by KWL.

1.1 Abbreviations Used

The following standard water loss management terms and abbreviations used in this Report and the AWWA M36 Water Audits and Loss Control Programs Manual:

ADD = Average Day Demand
BD = Base Demand (Typical Winter Demands)
Ca = Capita (Person)
HGL = Hydraulic Grade Line
ICI = Industrial, Commercial, and Institutional
ILI = Infrastructure Leakage Index
MDD = Maximum Day Demand
MMCD = Master Municipal Contract Documents
OCP = Official Community Plan
PHD = Peak Hour Demand
PRV = Pressure Reducing Valve
SCADA = Supervisory Control and Data Acquisition
SD = Seasonal Demand (Typical Irrigation Demand)
ML/Yr = Unit of measure - Mega Litres of water per year
ML/d = Unit of measure - Mega Litres of water per day
mH = Unit of measure – System pressure expressed in meters (head)
km = Unit of measure – Length of mains in kilometers

1.2 Reference Materials, Assumptions and Limitations

Reference Materials

Preparation of this report has proceeded with the benefit of the following reference materials:

City of Nanaimo Reference Materials

1. City of Nanaimo AutoCAD drawing files which include pressure zone boundaries, PRV locations and water main information.
2. Monthly and Daily Bulk water meter readings (from SCADA).
3. Customer meter readings (billed on a 4-month cycle) accessed from the City's Tempest database.
4. City's current tracking sheets characterising daily consumption, population and system characteristics.
5. Detail of water main breaks from 2007 – 2011.

Other Reference Materials

1. AWWARF, 2016, M36 Water Audits and Loss Control Programs, Fourth Edition
2. AWWARF. 2007. Evaluating Water Loss and Planning Loss Reduction Strategies. Denver, Colo.: AWWA Research Foundation.

2. Top-Down Water Audit

The sub-sections included in this section reference the task numbers one (1) through eleven (11) outlined in Chapter 2 of the M36 manual. All references to a particular "Task" is done such that the reader may refer with ease to the appropriate section of the M36 manual.

2.1 Compiling the Top-Down Water Audit Data

An AWWA M36 water audit is an effective tool for quantifying consumption and losses that occur in the distribution system as well as apparent losses that occur within the management processes related to customer metering and billing practices.

The water balance summary sheet that summarizes the audit results is shown in Figure 2-1. The balance sheet shows the sources of non-revenue water, such that large sources of non-revenue water, including water losses, can be identified and managed.

<table>
<tr><td rowspan="10">System Input Volume</td><td rowspan="5">Authorized Consumption</td><td rowspan="3">Billed Authorized Consumption</td><td>Billed Water Exported</td><td rowspan="3">Revenue Water</td></tr>
<tr><td>Billed Metered Consumption</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non-revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Figure 2-1: AWWA M36 Water Balance

The accuracy of the top down water audit on assessing water losses relies on accurate source data, good record keeping, and a high percentage of metered customers in the network. The audit gathers all available records and places data in a water audit worksheet.

System Boundaries

The water audit was performed for the treated water transmission and distribution system as bounded by the City's source and customer meters. For the purpose of an AWWA water audit, source refers to the point where treated water enters the distribution system. The source water is metered at the Water Treatment Plant that is supplied by the South Fork Reservoir.

Raw water transmission mains from the South Forks reservoir are not included in the water audit as they are upstream of the metering location.

Time Period

A one year period is recommended for completing the audit as this allows for seasonal variations in demand and reduces the effects of lag time in customer meter reading. The audit period used was from August 1, 2015 to July 31, 2016. This period reflects the most recent complete dataset collected by meter readers as of August 2017. This data period includes 366 days given that 2016 was a leap year.

Units of Measure

The units of measure used in the water audit are **metric.** Water volume is given in mega-litres per year (ML/Yr), average operating pressures are given in metres head (mH) and length of water mains is expressed in kilometers (km).

2.2 Task 1 – Collect Distribution System Description Information

The physical characteristics of the water system are required in order to calculate key performance indicators. Pertinent characteristics of the City of Nanaimo's water system are listed below:

- 636.2 kilometers of water mains (excluding hydrant connections);
- 255.7 kilometers of service connections.
- 18.0 kilometers of hydrant and air-release service connections;
- 25,571 customer accounts;
- 26,119 customer meters (*Note: some customers have multiple meters*);
- 3,114 City owned fire hydrants;
- 547 Privately owned fire hydrants;
- 26 pressure zones with 51 pressure reducing stations and 10 surge release stations (from 2011 Water Audit);
- 10 reservoirs (from 2011 Water Audit); and
- 7 active (online) pump stations and 3 stand-by pump stations (from 2011 Water Audit).

The city has a service connection density of 40.2 connections per km of mains.

The system is operated at an average pressure of 71.5 meters head. This statistic was taken from the 2011 Water Audit.

2.3 Task 2 – Measure Water Supplied to the Distribution System (Source Flow Data)

Compile Source Volume Raw Data

Water supplied into the system is measured at the City's water treatment plant that was commissioned December 4, 2015. The plant has three raw water inlet pipes that are metered by 20" Endress Hauser magnetic flow meters. The plant consists of seven primary membrane cells that are all individually metered by seven 16" Endress Hauser magnetic flow meters and four secondary membrane cells that are individually metered by four 6" Endress Hauser magnetic flow meters. The meters are approximately one and a half years old. Source data for August 1, 2015 through December 4, 2015 is assumed to include data from the City's now decommissioned water process centre flow meters.

Table 2-1 displays the 2016 source flow totals as provided by the City.

Table 2-1: 2016 Monthly Source Flow Volumes

Month	Volume (ML)
August 2015	1,455
September 2015	1,119
October 2015	957
November 2015	881
December 2015	908
January 2016	918
February 2016	862
March 2016	961
April 2016	1,122
May 2016	1,488
June 2016	1,451
July 2016	1,586
Total	**13,707.2**

The total metered source volume for the audit period was 13,707.2 ML.

Source Adjustments

Once the source volumes are established (raw data), the measured amounts need to be reviewed and corrected for known systematic or random errors that exist in the data. Factors to be considered in this adjustment include:

1. Meter inaccuracies;
2. Changes in reservoir and storage levels; and
3. Other adjustment such as losses occurring before water reaches the distribution system.

Given the duration of the audit and the diurnal fluctuations in tank volumes, changes in storage are considered negligible.

The blow-off of treated water at the Duke Point Reservoir could be accounted for here; however it is instead accounted for as an authorized unbilled unmetered consumption. This is discussed further in the section covering authorized unbilled unmetered consumption.

For the purpose of the audit, the meters are assumed to have an accuracy of ±0.5% and sized to minimize low flow inaccuracies. A 0.5% under-registration is assumed. The yearly average metering inaccuracy due to low flow under-registration is therefore estimated to be to 68.5 ML/year.

Source Meter Adjustments for the Water Audit

The adjusted source volume for the audit is 13,775.7 ML given the assumed 0.5% source meter under-registration.

2.4 Tasks 3 & 5 – Quantify Authorized Consumption

Authorized consumption comprises:

TASK 3 – Quantify Billed Authorized Consumption

- Billed Water Exported.
- Billed Metered Consumption.
- Billed Unmetered Consumption.

TASK 5 – Quantify Unbilled Authorized Consumption

- Unbilled Metered.
- Unbilled Unmetered.

For the audit period:

Authorized consumption was calculated as 12,334.7 ML;

Billed Authorized Consumption was calculated as 11,064.3 ML; and

Unbilled Authorized Consumption was calculated as 1,270.4 ML.

The components of these figure are expanded upon below:

Billed Water Exported

In addition to its residents, the City also supplies water to the Village of Southwest Extension and Snuneymuxw Reserve No 1.

The City of Nanaimo has been supplying the Village of Southwest Extension with bulk water since 1998. Water is metered through a 50 mm Sensus touch read meter for low flow installed in 2008 and a 150 mm Sensus radio read meter for high flow installed in 2010. The total water exported to the village during the audit period was 48 ML.

The Snuneymuxw First Nation is supplied and billed for bulk water through four touch read Sensus meters. In 2009, a 200mm meter and a 75mm meter were installed. A 150mm meter was installed in 2012 and a 200mm Sensus touch read was installed in 2013. The total water exported to the Snuneymuxw Reserve No. 1 was 75 ML over the audit period.

The total water exported was therefore 123 ML over the audit period.

Billed Metered Consumption

The city has had universal metering of all service connections since 1983. It manages customer billing and meter reading using billing management software that stores meter readings and meter data including meter installation date, size and manufacturer.

There are 26,113 active billing meters in the network for 25,567 customer accounts (excluding bulk water export customers). Table 2-2 gives a summary of customer account types as defined in the meter database. It is noted that the account type listed in the database contains limited information for defining Industrial, Commercial and Institutional (ICI) customers however the level of detailed data is still very informative.

Table 2-2: Metered Customers by Account Type

Account Type[1]	Number of Meters	Number of Customer Accounts	Percent of Total Meters	Consumption	Percent of Metered Consumption
Commercial/Res	165	135	0.6%	159.5	1.5%
Government	150	88	0.6%	803.2	7.4%
Municipal	170	132	0.7%	408.5	3.8%
Other	2,161	1,933	8.3%	1,978.0	18.3%
Residential - MLT	4,889	4,708	18.7%	3,176.7	29.5%
Residential - SFD	18,578	18571	71.1%	4,258.5	39.5%
Total	**26,113**	**25,567**	**100.0%**	**10,784.4**	**100.0%**

Notes: [1]COMMERCIAL/RES refers to commercial/residential mixed-use account types. MLT refers to multifamily. SFD refers to single family dwellings.

It is noted that 89.8% of accounts are residential and residential consumption is approximately 69% of the total.

The total billed-metered consumption over the audit period was 10,784.4 ML.

Billed Un-metered Consumption

Billed Un-metered consumption includes 1,660 domestic connections, 2 municipal connections, one fire hall connection, one commercial connection (Imperial Oil Limited), and a bulk water filling station at Public Works.

Table 2-3 provides a summary of the billed un-metered customers and assumed average day consumption rates.

Table 2-3: Billed Un-Metered Customers and Assumed Average Day Consumption

Customer Description	Number of Customer Accounts	Assumed Average Day Consumption (L/day/cust.)	Estimated Yearly Volume (ML)
Single Family Dwelling	57[1]	495	10.3
Single Family Dwelling w Suite	9	650	2.1
Mobile Home (assumes 50% occupancy)	1,596	190	110.1
Fire Hall	1	4,110	1.5
Municipal/Govt.	2	1000	0.7
Commercial	1	1000	0.4
Total	**1,666[1]**	**NA**	**125.1**

Notes:
[1] 2 accounts have 2 single family dwellings attached to the account. The actual total number of customer accounts is 1,664 and not 1,666.

The city operates two bulk filling stations. The Duke Point station is metered and the Public Works station is not metered. At the Public Works station customers are charged for water based on the size of tank filled and volumes are recorded for billing purposes.

The City operates two bulk filling stations. One The city operates a bulk filling station where customers are charged for water based on the size of tank filled. Volumes are recorded for billing purposes but not metered.

Bulk water hauling spreadsheets were provided for the period of January through December 2016. It is noted that this period differs from the audit period. It is assumed that the 2016 calendar year data will closely reflect that of the audit period. Table 2-4 summarizes bulk water filling by customer.

Table 2-4: 2016 Billed Unmetered Consumption by Business

BUSINESS USER	Volume (ML)
Acer Landscaping	0.03
DBL Disposal Services	0.08
Groess Environmental	0.11
Haylock Bros. Paving Ltd	0.02
Hub City Paving	0.05
Island H20 Services	17.76
Island Water Hauling	12.94
Lush Lawns Hydro-seeding	0.06
Pro West Services	0.08
Osborne Outdoor	0.00
Pipe Eye Video Inspections	0.12
South Island Power Sweeping	0.06
Summer Rain Water Deliver	0.39
Van Island Powerline Ltd	0.11
TOTAL	**31.8**

The total volume of billed unmetered consumption was 156.9 ML.

Unbilled Metered Consumption

There are 14 accounts with meters that are not billed. Table 2-5 below gives a list of these accounts.

Table 2-5: Unbilled Metered Consumption

Account Number	Volume (ML)	Description	Account Type
101799	0.000	HARBOUR CITY LAUNDRY (DEMO'D)	OTHER
104357	0.000	GARDEN AREA	OTHER
106110	0.001	OLD MADILL BUILDING	OTHER
106942	0.091	SFD	RESIDENTIAL-SFD
108672	0.000	RESTAURANT - RESIDENTIAL	COMMERCIAL/RES
111112	0.000	GREEN SPACE @ HWY/METRAL	OTHER
117741	0.000	NOT IN USE	RESIDENTIAL-SFD
120190	0.142	OUTSIDE CITY - SPECIAL AGREEMENT NOT TO BILL	RESIDENTIAL-SFD
200638	0.000	PARKWAY IRRIGATION	OTHER
200639	0.000	PARKWAY IRRIGATION	OTHER
200677	0.000	PARKWAY IRRIGATION	GOVERNMENT
200678	0.000	PARKWAY IRRIGATION	GOVERNMENT
200679	0.000	PARKWAY IRRIGATION	OTHER
202788	0.000	ARMY CAMP	GOVERNMENT
202788	0.003	ARMY CAMP	GOVERNMENT
TOTAL	**0.24**		

Unbilled metered consumption was 0.2 ML.

Unbilled Un-Metered Consumption

Unbilled un-metered consumption includes water used by the City of Nanaimo for operational purposes. Components of unbilled un-metered consumption are given below in Table 2-6.

Table 2-6: Estimated Unbilled Un-metered Consumption

Source	Volume (ML/Yr)	Data Source / Summary
Yearly Flushing	13.5	Water distribution staff completed approximately 50 days of flushing in 2016. The volume of flushing water was estimated from the average daily volume in 2011.
Water Sampling Stations	55.5	The City has 12 sampling stations that run continuously. Flow rates were estimated based on average operating pressure and orifice size and then provided to Nanaimo Operations staff. The volume used is from the 2011 Water Audit (Assumes no changes).
PRV Sump Priming	157.7	The City has approximately 20 sumps in PRV stations that are primed with treated water. Operations staff estimates the total flow rate at these sites to be approximately 5 L/s.
Fire Fighting	2.8	The city estimates that 6-10 fires occur yearly. 350 m^3 is the estimated yearly firefighting volume.
Duke Point blow-off	1,040.7	The City continuously blows off water at the Duke point reservoir in order to maintain adequate water age. The Duke point industrial area currently has low demands. The City has previously estimated this flow rate at 33 L/s.
TOTAL	**1,270.2**	

The total unbilled un-metered consumption is estimated at 1,270.2 ML/year.

The largest component of unbilled un-metered consumption occurs at Duke Point reservoir. Figure 2-2 provides photos of this blow-off. The blow-off was added to decrease water age as the Duke Point reservoir and distribution piping are sized for a much larger industrial demand than what currently exists.

Figure 2-2: Photos of Duke Point Reservoir and Blow-Off

2.5 Task 4 – Calculate Non-revenue Water

Non-revenue water is the portion of water that the City treats and distributes that is not billed and therefore does not generate revenue for the City. Non-revenue water consists of unbilled authorized consumption (discussed above), apparent losses and real losses. In the top-down audit approach, non-revenue water is calculated as the remaining water into supply that is not accounted for within the billing records. This is shown as:

Non-Revenue Water = Adjusted Source Volume (Task 2) – Billed Authorized Consumption (Task 3) = 13,775.7 ML - (123ML + 10,784.4 ML + 156.9 ML) = **2,711.4 ML**

2.6 Task 6 – Quantify Water Losses

Water losses are made up of apparent and real losses. In the AWWA water audit approach, water losses are determined as the adjusted source volume minus authorized consumption. Put in another way, water losses are non-revenue water minus unbilled authorized consumption. **Water losses are estimated as 1,441.0 ML (including both apparent and real losses).** This is given as:

Water Losses = Non-revenue water (Task 4) – Unbilled Authorized Consumption (Task 5) = 2,711.4 ML – (0.2 ML + 1,270.2 ML) = 1,441.0 ML

2.7 Task 7 – Quantify Apparent Losses

Apparent losses are those that are caused by incorrect meter reads, data handling errors, billing system accounting practices, meter under-registration and water taken without permission. **Apparent losses were calculated to be 301.7 ML**.

Apparent losses consist of three main components:

1. Customer metering inaccuracies;
2. Data-handling errors; and
3. Unauthorized consumption.

The components of apparent losses and calculation assumptions are given below.

Customer Metering Inaccuracies

The extent of customer metering inaccuracy was estimated in the 2011 Water Audit by performing testing on a representative sample of meters. We assume customer meter inaccuracies have not changed since the 2011 Water Audit.

The following meter accuracies were estimated in the 2011 Water Audit:

- 98% for the 19mm meter population.
- 97.2% for the large meter population (25mm – 250mm)
- 97.8% overall meter accuracy.

Apparent losses due to metering inaccuracies were therefore estimated at 240.0 ML/year.

Systematic Data Handling Errors

Systematic data handling errors are apparent losses associated with the handling of retail water meter billing system. Errors are associated with estimates due to missed meter reads, errors in meter reads, and customer billing disputes and leak credit adjustments that make their way into the meter read database.

The customer billing data was reviewed and no clear errors were found. The AWWA recommends a minimum default value of 0.25% of billed authorized consumption be attributed to data handling errors.

Systematic data handling errors were therefore estimated at 27.3 ML/year.

Unauthorized Consumption

The main causes of unauthorized consumption are:

1. Illegal connections;
2. Misuse of fire hydrants and firefighting systems; and
3. Vandalized or bypassed consumption meters.

Improper use of fire hydrants, such as unauthorized filling of tanker trucks is difficult to account for and control.

The City's billing department stated that they encounter a number of bypassed consumption meters. When found these accounts are adjusted based on average previous use over the billing period or an estimated use based on population (for meters found to be bypassed prior to occupancy). This usage is accounted for above; however, other sources of unauthorized consumption will exist. AWWA recommends that unauthorized consumption be estimated as 0.25% of source flows.

Un-authorized consumption is therefore estimated to be 34.4 ML/year.

2.8 Task 8 – Quantify Real Losses

Real losses include water that has been extracted from a water source, treated, and transported a distance before being lost from the distribution system.

Real losses are calculated as the system input volume minus authorized consumption and apparent losses. **Real losses are therefore estimated to be 1,139.3 ML/year.**

Components of Real Losses

The last component of the water audit is to estimate the distribution of real losses from transmission mains, service connection and reservoirs. No field data on reservoir leakage has been completed and no historical reports of uncontrolled reservoir leakage. Reservoir leakage is therefore assumed to be negligible.

The distribution of real losses between transmission mains and service connections is assumed to be equal to that of reported leakage. Service connection leakage is estimated as 67% of reported leakage and therefore the total leakage from service connection is estimated as 763.3 ML/year. Transmission main leakage is therefore estimated at 376.0 ML/year.

2.9 Task 9 – Assign Costs of Apparent and Real Losses

Determining the cost impacts associated with apparent and real losses is equally as important as the tracing of the volume of each component of the water balance.

The unit cost implications of apparent and real losses are not equal. Apparent losses are losses associated with real consumption that would otherwise produce revenue, whereas, real losses, due to such things as main breaks, don't affect customer revenues but do affect operational costs such as the costs to chlorinate water and pump it as required. Apparent losses are therefore valued at the retail cost that is charged to the customer and real losses are valued at the variable production costs to treat and deliver water.

The Cost of Apparent Losses

In 2016 the city utilizes a fixed daily charge plus a volumetric inclining block rate structure for water billing. The average volumetric charge, represents the cost of apparent losses and excludes the daily base charge.

The average rate charged by cubic meter of water ($/m^3) can be calculated from the City's 2016 water rate structure. The average 2016 daily customer demand across all customer types was 1155 L/account/day. Applying the City's inclining block structure, the average unit rate charged for water calculated as follows:

First 659 L (145 Gallons) @ $0.0002772/L = $0.1826

Next 341 L (75 Gallons) @ $0.001278/L = $0.4358

Next 155 L (34 Gallons) @ $0.001344/L = $0.2083

TOTAL (1,155 L) = $0.8267

Cost per m^3 (1,000 L) = $0.716/$m^3$

The cost of apparent losses is $0.716/$m^3$ or $716/ML

Table 2-7 provides the costs of apparent losses in 2016.

Table 2-7: Cost of Apparent Losses by Source in 2016

Source of Apparent Loss	Yearly Volume (ML)	Yearly Cost ($)
Unauthorized Consumption	34.4	$24,600
Customer Metering Inaccuracies	240.0	$171,800
Systematic Data Handling Errors	27.3	$19,500
Total	**301.7**	**$215,900**

The Cost of Real Losses

The cost of real losses includes all costs attributed to delivering the water to the leak location. Specifically this includes the unit cost for treatment (chemicals, power) and delivery to the leak (pumping power costs).

All costs associated with the treatment and distribution of water are given in Table 2-8.

Table 2-8: 2016 System Operating Costs (as Provided by the City

Cost Elements	Resources Section	Operations Section	
	South Fork Water Treatment Plant	Water Supply	Water Distribution
Utilities (Energy)	$134,935	$107,977	$185
Materials & Supplies	$191,596	$72,683	$444,815

The unit cost of real losses is calculated as the sum of South Forks Water Treatment Plant materials and supplies ($191,596) and sum of all system energy costs ($243,097) divided by the total volume of water supplied (13,775.67 ML).

The cost of real losses is calculated as:

$434,693 / 13,775,670 m^3 = **$0.0316/$m^3$ or $31.6/ML**

The cost of real losses during the audit period (1,139.3 ML) was approximately $36,000.

The real cost of water losses for the City is more accurately the cost of the potentially recoverable volume of real loss. When this is considered, the cost of real losses to the City is quite low at $4,100. See the following section for the calculation of the potentially recoverable volume of real loss.

2.10 Task 10 – Calculate Performance Indicators

Infrastructure Leakage Index

The Infrastructure leakage index is the ratio of current annual real losses (CARL) to unavoidable annual real losses (UARL). The ILI is a highly effective performance indicator for comparing and benchmarking the performance of utilities in operational management of real losses. Table 2-9 presents the components used in the calculation of the ILI. The formula used is presented below:

ILI = CARL/UARL

*UARL = (18*Lm + 0.8*Nc + 25 Lp) * P*

where;

Lm is the length of distribution mains (in km);
Nc is the number of meters;
Lp is the length of service connections (in km) assumed as 10 m times # of service connections; and
P is the average pressure of the system (in m head).

Table 2-9: ILI Calculation

Lm (km)	Nc (#)	Lp (km)	P (mHead)	UARL (ML/Year)	CARL (ML)	ILI	Potentially Recoverable Volume of Losses
654.2	25,571	255.7	71.5	1,008	1,139.3	1.13	131.3

An ILI of 1.13 represents a very well-run distribution system with no practical room for additional leak reduction. As the ILI approaches 1, costs increase to achieve additional loss reductions because of the level of effort to locate smaller and smaller leaks. The 131.3 ML of potentially recoverable leakage costs the City approximately $4,100/year, and would likely not be reduced with additional leak reduction effort as the majority of this leakage will be attributed to small weeping leaks on service connections.

Residential Water Use Efficiency

Residential water use is the focus of many demand management strategies and thus assessing the per capita indoor consumption and seasonal water use is useful for gauging the success of these programs as well as recommending areas for improved efficiency.

A disaggregated demand analysis was completed in the 2011 Water Audit to calculate base and seasonal use across all customer types. Average residential demand, average residential indoor water use and average single family residential seasonal demand were key performance indicators provided in the 2011 Water Audit.

Average day demand for single family dwellings, SFD, in 2016 is calculated as the total demand for the SFD customer type divided by the number of customer accounts. A comparison of monthly source meter volumes and average SFD usage between 2011 and 2016 can be used to estimate average indoor and seasonal water use for 2016.

Residential single family average day demand was calculated as 242 L/capita/day in 2016; a decrease of 22 L/capita/day or 8% from 2011. Table 2-10 provides the calculated average day demand for single family dwellings as well as the average for all account types. Also provided is the percent change from 2011.

Table 2-10: Average Day Demands for Residential Single Family and Overall All Account Types

Account Type	Number of Customer Accounts	Assumed Population Density	Consumption (ML/year)	ADD (L/account/day)	ADD (L/cap/day)	% Change (Per Meter) from 2011 Audit[2]
Res - SFD	18,571	2.6	4,258.5	628	242	-8%
ALL ACCOUNTS	25,567	NA	10,784.4	1,156	NA	-7%

Table 2-11 provides monthly source flows for 2016 and 2011 along with the estimated change in customer consumption. The data from October through January shows an approximate 8% reduction in base customer demand across all account types.

Table 2-11: Comparison of Monthly Source Flows (2011 and 2016)

Month	2016 Audit Volume (ML)	2011 Audit Volume (ML)	% Change (2011 to 2016)	Difference in Non-Revenue (2011 to 2016)	Estimated Change in Consumption (2011 to 2016)
Aug	1,455	1,990	-27%	-124	-26%
Sep	1,119	1,629	-31%	-124	-29%
Oct	957	1120	-15%	-124	-9%
Nov	881	1038	-15%	-124	-9%
Dec	908	1052	-14%	-124	-7%
Jan	918	1058	-13%	-124	-7%
Feb	862	938	-8%	-124	1%
Mar	961	1082	-11%	-124	-5%
Apr	1,122	1,082	4%	-124	11%
May	1,488	1,160	28%	-124	36%
Jun	1,451	1,497	-3%	-124	0%
Jul	1,586	1,805	-12%	-124	-10%
Total	13,707.20	15,451.00	-11%	-1,489.60	-7%

Per-capita indoor or base water demand is approximated at 182 L/capita/day in 2016, down 8% from 198 L/capita/day in 2011.

Total yearly seasonal demands are estimated by subtracting average base demand and leakage volumes of 1022 ML/month in 2011 and 892 ML/month in 2016 from the total yearly source volumes. The total volume of seasonal demand decreased from 3193 ML in 2011 to 3000 ML in 2016. This represents a 6% reduction in seasonal demands.

Task 11 – Compile the Water Balance

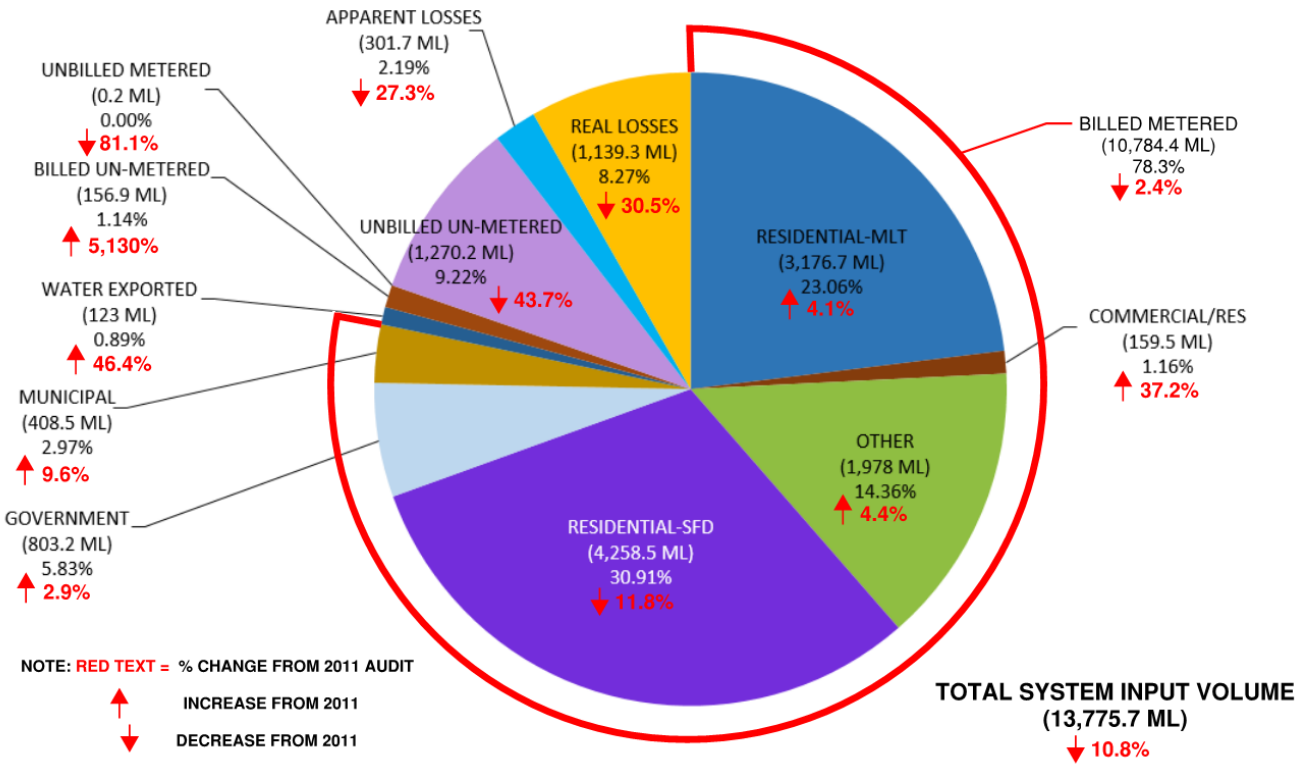
A summary of the water balance results is presented below in Table 2-12.

Table 2-12: Water Audit Results

<table>
<tr><td rowspan="10">System Input Volume
13,775.7 ML</td><td rowspan="3">Authorized Consumption
12,334.7 ML</td><td rowspan="2">Billed Authorized Consumption
11,064.3 ML</td><td>Billed Water Exported
123 ML</td><td rowspan="3">Revenue Water
11,064.3 ML</td></tr>
<tr><td>Billed Metered Consumption
10,784.4 ML</td></tr>
<tr><td>Billed Unmetered Consumption
156.9 ML</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
1,270.4 ML</td><td>Unbilled Metered Consumption
0.2 ML</td><td rowspan="7">Non-revenue Water
2,711.4 ML</td></tr>
<tr><td>Unbilled Unmetered Consumption
1,270.2 ML</td></tr>
<tr><td rowspan="5">Water Losses
1,441.0 ML</td><td rowspan="3">Apparent Losses
301.7 ML</td><td>Unauthorized Consumption
34.4 ML</td></tr>
<tr><td>Customer Metering Inaccuracies
240.0 ML</td></tr>
<tr><td>Systematic Data Handling Errors
27.3 ML</td></tr>
<tr><td rowspan="3">Real Losses
1,139.3 ML</td><td>Leakage on Transmission and Distribution Mains
376 ML</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks
0 ML</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering
763.3 ML</td></tr>
</table>

2.11 Summary of Results

The results of the 2016 Water Audit are summarized in the chart below along with the percent difference that each component changed from 2011.



The City made positive changes in every aspect of the water audit when compared to 2011.

2.12 Recommendations

We recommend the City continue ongoing efforts and budgets, recommended in the 2011 Water Audit, for the replacement of customer meters.

We recommend the City complete updates to the water audit on a yearly basis. This work is estimated at $10,000 / year.

Report Submission

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Revision History

Revision #	Date	Status	Revision	Author
0	November 6, 2017	Draft Report	-	RYL
1	January 29, 2018	Final Report	Additional information on per-capita usage.	RYL